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MANAGEMENT ORGANIZATION AND THE COMPUTER

FIRST SERIES (1916–1938)

Materials for the Study of Business

EDITED BY DEAN LEON CARROLL MARSHALL AND
DEAN WILLIAM HOMER SPENCER

SECOND SERIES (1938–1956)

Business and Economic Publications

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THIRD SERIES (1959–)

Studies in Business

EDITED BY DEAN W. ALLEN WALLIS

Management Organization
AND THE
Computer

Proceedings of a Seminar Sponsored by
Graduate School of Business—University of Chicago
and The McKinsey Foundation

Edited by GEORGE P. SHULTZ
and THOMAS L. WHISLER

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Foreword

THE PRESENT SERIES continues a publication program which the Graduate School of Business inaugurated in 1916. During World War I, the School (then known as the School of Commerce and Administration) sponsored a series called *Materials for the Study of Business,* designed for the purpose of "organizing the business curriculum into a coherent whole." Under the editorship of Dean Leon Carroll Marshall and Dean William Homer Spencer, over fifty titles were published through the University of Chicago Press, many of which have become classics in the field. Among these are:

John Maurice Clark, *Social Control of Business,* 1926. *Studies in the Economics of Overhead Costs,* 1923.
Paul H. Douglas et al., *The Worker in Modern Economic Society,* 1923.
Charles O. Hardy, *Risk and Risk-Bearing,* 1923.
James O. McKinsey, *Managerial Accounting,* 1924.
Harold G. Moulton, *The Financial Organization of Society,* 1921.
Theodore O. Yntema, *A Mathematical Reformation of the General Theory of International Trade,* 1932.

In 1938 the name of the series was changed to *Business and Economic Publications,* and under the editorship of Dean Spencer thirteen volumes were published through the McGraw-Hill Book Company, the last in 1953. They included:

Harry A. Millis and Royal F. Montgomery, *The Economics of Labor* (3 vols.), 1938.
Edward A. Duddy and David Revzan, *Marketing: An Institutional Approach,* 1947.
Billy E. Goetz, *Management Planning and Control,* 1949.

Concurrently with its series of books, the School published a monograph series, *Studies in Business Administration,* in which some seventy works appeared between 1929 and 1948, when the monograph series was discontinued.

The present series is in part a new venture in that it will differ from its predecessors both in scope and in content. In part, it simply continues the older tradition of publishing fundamental and applied research which contributes new knowledge and ideas important for the practice of business.

W. ALLEN WALLIS
DEAN
GRADUATE SCHOOL OF BUSINESS
UNIVERSITY OF CHICAGO

Preface

THIS BOOK REPORTS the proceedings of a Seminar on management organization and computers sponsored by the McKinsey Foundation. The McKinsey Seminar, held in February, 1959 at the Graduate School of Business, the University of Chicago, consisted of two and one half days' discussion of eleven papers. The papers, expressly written for the Seminar, discuss various aspects of a new kind of technological change—the processing of business information. The purpose of the Seminar was to assess the nature of this change and its significance for the group of workers most directly affected—business managers. The Seminar was restricted to a small group of informed participants, and extended over a period of time long enough to permit an intimate and detailed exchange of views.

In selecting a topic for and organizing the Seminar, the editors of this volume had the help and support of Deans W. Allen Wallis and James H. Lorie at the Graduate School of Business. They made suggestions about ways to define the subject matter, put us in contact with men who could aid us in identifying significant and relevant industrial experience, and supported us by their presence during parts of the Seminar. At the same time, they left final decisions completely in our hands, so that we were free to run things in our own way. This kind of help combined with confidence is rare, and we wish to express our appreciation for it.

The McKinsey Foundation provided us with the necessary funds. In addition, the Foundation was in large part responsible for the idea of this kind of seminar, and was also a helpful source of suggestions on the format for the discussion and on industrial experience of relevance to our topic. We wish in particular to acknowledge the helpful suggestions of Mr. Forrest Wallace, member of the Foundation Board of Directors, and Mr. Henry B. DuFlon, the Foundation's Executive Director.

Even a glance at the table of contents shows how heavily this volume rests on the contributions of our colleagues on university faculties and of the industrial participants in the Seminar. Each of the men involved gave freely of his ideas and experiences, so that we all were able to emerge from the intensive discussions with a deeper understanding of the subject matter than we had some two and one half days earlier. We wish to thank those who took part in the Seminar, and the outstanding organizations from which they came, for the quality of their efforts and for their willingness to share their knowledge with others.

The arrangements for our meetings were made and much of the work involved in preparing this volume was done by Mrs. Nettie Breslin. Final typing and assembly of the book was done by Laura D. Wolf. Carol Fernstrom provided editorial assistance. Along with the work, they all provided wit and charm to help lighten the burdens of our own responsibilities. We wish to thank them for this unusual combination of talent and effort.

We wish also to thank William L. Libby, Jr. for his work on preparation of the index.

George P. Shultz
Thomas L. Whisler

Chicago, Illinois
October 19, 1959

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INTRODUCTION

Rapid and extensive progress has been made during the last decade in the application of quantitative techniques and computers to the analysis of the problems of business management. These developments amount to an important technological change affecting the techniques of managing. What effect will these developments have upon management jobs, organization, and philosophy?

The structure of business organizations and the content of management jobs within them reflect the organization's processes of decision-making and the flows of information used to reach those decisions. The technology under discussion here is a means of organizing information, of relating it to various managerial decision problems, and, in many instances, of working out decisions based on predetermined and programed rules. If this "information technology" is important, as we believe it is, its use implies changes in the content of many management jobs and in the structural characteristics of the organization.

Changes of this sort follow more or less directly from the nature of the technology, but new organizational arrangements, and the job shifts people must make in connection with them, generate problems for management and even some issues for society at large. How will the changes affect the level of centralization in decision-making? Who should be selected for the new tasks, and how should they be trained? What patterns of compensation are most appropriate and how will these fit into the traditional structure of compensation in the organization? What impact will these changes have on appropriate methods for management development? How may individuals and the organization itself best adapt to the process of change? What will happen to career patterns and to work satisfactions?

The resolution of questions such as these does not end matters. The answers that are developed feed back in turn on the technology itself and the way it is used. The same technology may succeed or fail in similar organizations, depending upon the way in which installation of the technology is managed. We have here, then, a twofold problem. We must examine the impact of new technology on the management organization and on the problems with which management must deal. At the same time, we are interested in the way organization developments affect the nature and use of the technology itself.

This volume reports on two and one half days of discussion about these issues. Six members of university faculties were joined by seven men from the business community to form a group with a wide range of interests and talents relevant to the use of "information technology" in business firms. Represented were the viewpoints of men with responsibility for management decisions at the top level; experience with the installation and use of new information systems in businesses of varying size and with widely different marketing, production, and organizational characteristics; technical and scientific competence to judge the present and emerging forms of the technology involved; a comprehensive grasp of what is known, and not known, in the fields of organization structure and of human response to the forces at work in organizations; and experience with research and with the processes of acquiring new knowledge.

This book is organized into four parts: (1) a synthesis of ideas about the impact of information technology on management jobs and organization problems; (2) analysis of the technological developments whose impact is under review here; (3) presentation of key considerations about organizational matters; and (4) case studies of experience in five companies. The raw materials are papers prepared by individual authors, amplifying comments made by some of the authors at the Seminar, and excerpts from the discussion. Much of the discussion, however, appears as part of the papers themselves.

In Part I the editors present their views on the ways information technology will affect management jobs and on the consequent problems to be faced by management. The reader will find here a discussion of effects on jobs at various levels in the organization and on various types of staff activities. In addition, this paper deals with issues such as the compensation of managers, the problems of training and management development, the degree of centralization in decision-making, and the adjustment of individuals and the organization to important technological change. Finally, some suggestions are made for appropriate research.

Part II deals with technological developments. Two papers, one by Herbert A. Simon and Allen Newell, and the other by Alex Orden, are supplemented with remarks by Simon and excerpts from discussion at the Seminar. These materials deal largely with the digital computer and take up two types of questions. The first type involves technical developments:

1) *What is a computer?* What is a useful image of this machine—one that will move us from bemused fascination with the wires, tubes, tapes, and speeds of electrical impulses, to an understanding of its major attributes and capacities?

2) *What is the technical potential of the computer?* What range of tasks has it accomplished, can it accomplish?

3) *How does the computer relate to other elements of information technology,* to the statistical and mathematical decision techniques so prominent in recent years?

The second type involves the use of these developments:

1) *In what way does the computer relate to the world of the administrator?* How is its behavior analogous to what we call decision-making, to business systems, to choice-making?

2) *What is the time scale on computer applications?* Where are we today? When may we expect to reach the technical potential we already foresee?

3) *What can we say about the economics of computers?* What appear, at the present time, to be the areas in which it is most likely to supplant human efforts, what areas least likely?

In Part III Douglas McGregor and Alex Bavelas discuss two organizational questions of general interest but of particular relevance to the use of information technology. McGregor concentrates on the role of staff people in organizations and the way this role is changing with new technological developments and with greater understanding of how organizations work. In addition, he presents strong views about the effects on the organization of different ways of introducing this new technology. Bavelas develops some relationships between an organization's communication problems and its structural properties.

Part IV presents experience selected from work now going on in five companies where applications of one aspect or another of information technology have progressed further than in most other firms. A diversity of company situations and experiences are represented. Four of the firms rank with the giants of American industry —although that still allows great variation in size. In addition, one of the firms is of medium size, employing a little over one thousand people. In at least one case the use of information technology was approached with great urgency, while in the others the pace of introduction was somewhat less forced. Initial organizational arrangements varied widely, in terms both of the position in the company of those primarily responsible for the new developments, and of the company organization structure and the traditions into which these developments were placed. And, of course, the products, their market, and the methods of manufacture are completely different in each firm.

Despite this diversity, much common ground can be identified. The systems designed laboriously for one company and its specialized problems turn out to be quite similar, in broad outline, to those worked out for others. And, at the organizational level, common problems, frustrations, and, to a certain extent, structural developments, seem as easy to identify as the special characteristics that make each case unique in some way.

The case of International Shoe Company is presented by Leonard F. Vogt. It illustrates a broad application of information technology, conceived at the corporate rather than the divisional level. The comments of John Hines suggest that systems he has developed at the Distribution Transformer Department of the General Electric

Company are strongly similar to those in use at International Shoe, despite the facts that the products produced and the markets served are altogether different. The United Air Lines experience, presented by Warren E. Alberts, introduces a somewhat different conception of the application of information technology, bringing to the forefront systems development and the "corporate laboratory." The experience at Standard Oil Company of New Jersey is presented by two men—Melvin H. Grosz, emphasizing technical developments, and Carl H. Rush, organizational changes. Together they give us a picture of the process of growth of this technology in a very large international company constructed of loosely coordinated subsidiaries and affiliates. The final case study—the Atwood Vacuum Machine Company, presented by Seth G. Atwood —provides a rather startling contrast to the others, particularly because it is so much smaller. The experience here suggests the pervasiveness that information technology may attain in American business. While discussion of these cases emphasizes technical and organizational issues, it also puts information technology into perspective as one aspect, albeit an important one, of the more general management function. The comments of Lemuel Hunter were particularly helpful in this regard.

PART I

Information Technology and Management Organization

"Projections of future developments almost automatically lead to the questions:

What are the concurrent problems which will arise?
What should be done about them?"

INFORMATION TECHNOLOGY AND MANAGEMENT ORGANIZATION

By

Thomas L. Whisler and George P. Shultz[*]

WITHIN THE LAST DECADE we have seen rapid and extensive progress in the application of quantitative techniques to the analysis of management problems. Three areas of activity are involved: (1) the use of mathematical and statistical methods, with or without the aid of electronic computers; (2) the use of computers for mass integrated data processing; and (3) the direct application of computers to decision-making through simulation techniques. These areas are clearly interdependent, although the nature and degree of interdependence are still undergoing exploration. We will lump these areas together here under the heading "information technology," a phrase used by one of the authors in an earlier paper from which we have drawn many ideas.[†]

In many ways, these developments represent an application, to the private and civilian sector of the economy, of ideas and technology initially nourished and developed by the Federal Government for scientific uses connected with the military. Business organizations are moving rapidly into this field, however, and already many problems and broad lines of development, both technical and organizational, are apparent. In this paper, we will make as much use as possible of the experience now available to suggest (1) the impact of information technology on decision-making, (2) the kinds of changes that may occur in the structure of management jobs, and (3) some of the personnel and organizational problems likely to be associated with these changes. We have given ourselves the advantage of the discussion and ideas of the members of this Seminar.

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[*] Respectively Associate Professor and Professor of Industrial Relations, Graduate School of Business, University of Chicago.

[†] Harold J. Leavitt and Thomas L. Whisler, "Management in the 1980's," *Harvard Business Review,* Vol. XXXVI, No. 6 (November–December, 1958).

THE GROWTH OF INFORMATION TECHNOLOGY

One standard of measuring the impact of new ideas and techniques is in terms of the speed and extent of their acceptance. The evidence on information technology, although sketchy, is impressive.

Informed but informal estimates by representatives of computer manufacturers indicate that in September, 1959, there were approximately 460 large (IBM 705 or equivalent) and 1400 medium (IBM 650 or equivalent) computers in operation in business. This compares with the estimate in *Fortune* (October, 1959) of 400 large, 1200 medium, and 1000 small machines. These figures can be seen in perspective if we recognize that the number of installations of computers for business use was close to zero prior to 1956.

Production of computers for business applications really started in earnest in 1956, after a three-year period during which only a few exploratory installations were made following the highly publicized installation of Univac in the Bureau of the Census in 1952. Plug-board equipment was common in business use, but some new problems had to be resolved before the new computers could be used effectively in business. The problems lay partially in the computer itself (inadequate storage capacity, access, auxiliary equipment, reliability, and so on) and partly in visualizing the kind and scope of problems toward which machine design should point. Hence the three-year gestation period prior to 1956.

A second type of evidence of the growth and volume of work in the fields we have called information technology is the amount of writing and discussion concerned with them. New journals and organizations have been created; business firms using computers have themselves formed consumer organizations to share experiences and to influence the plans of equipment manufacturers; old organizations are devoting considerable time in their meetings and space in their publications to related technical and organizational questions.

Examination of the *Applied Science and Technology Index* and the *Business Periodicals Index* (formerly combined into the *Industrial Arts Index*) is revealing. In the 250 periodicals indexed, articles relating to computers and electronic data processing appeared, through recent years, in the following quantities:

Year	Number of Articles	Year	Number of Articles
1939–45	none	1952	94
1946	7	1953	127
1947	18	1954	157
1948	29	1955	194
1949	22	1956	254
1950	67	1957	367
1951	83	1958	509
		1959	717

Of the 367 articles published in 1957, 361 appeared in industrial publications, four in academic journals, and two in government publications. The industrial interest is evident. Inspection of other and relevant headings in this index, such as "Linear Programming," "Operations Research," and "Theory of Communication," reveals similar, though less dramatic, growth trends, and an even greater dominance of industrial publications.

Finally, in our listing of evidence we should note the very great variety in sizes and types of computers that are now available, and the applicability of quantitative techniques under review here to medium-sized as well as large businesses.*

The evidence suggests that we are experiencing a substantial and rapidly growing development, even though the technology itself is certainly not yet mature. But the speed with which it comes to individual firms and to the economy will reflect the limitations of people as well as technical developments. At least at the present time, the use of "information technology" to solve or illuminate business problems is, for any particular organization, a rather creative act. On the part of the higher echelons of management, it calls for some knowledge of the techniques, for confidence that the techniques involved can be used with success, and for insight into the areas within the business where the techniques may most readily be applied. Thus we will probably see here a well-known process in which a few especially imaginative innovators will pioneer, followed, after some time lag, by their imitators. The imitators, however, will almost surely have to spend considerable time adapting even well-proved techniques to the special characteristics of their particular operations. This is not too surprising—change involves not only new "hardware," but also the basic structure of management organization.

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* See, for example, Francis Bello, "The War of the Computers," *Fortune*, October, 1959, pp. 128–33, 160, 164, 166, 171.

Finally, a major factor governing the growth of information technology is the cost of using the computer. It is true that some of the techniques involved require no equipment, and no doubt important work has been and will continue to be done on a small scale and a rather *ad hoc* basis. Nevertheless, information technology seems unlikely to have any major impact on the management organization until it becomes almost a part of daily operating routines, usually through the use of a computer. Thus, high—though perhaps declining—costs seem to mean slow and careful movement and a tendency initially to seek routine applications certain to recapture costs, rather than the more analytical and risky applications in which we are most interested here. The problem of assessing the economic feasibility of alternative computer uses was itself a topic of discussion in the Seminar.

On the whole, then, we can say with some assurance that we are dealing with developments of considerable importance to management. The technology involved is already at work in a substantial number of cases and seems destined to spread until it is widely used. While there are brakes on the pace of introduction, use in any individual case is likely to mark a turning-point in that organization's life. It is well, then to explore as soon and as completely as possible the implications of information technology for managers and management organization.

THE IMPACT OF INFORMATION TECHNOLOGY ON DECISION-MAKING

Quantification

However fast and far information technology moves into use in business organizations, the nature of its impact on the decision-making process seems clear, at least in broad outline. The techniques themselves feed on numbers and on systems, the elements of which are explicit and unambiguous. Wherever these techniques are adopted, they will bring with them increased emphasis on quantification of information about the firm's operations and its environment. At the same time, the firm's attention is directed toward making explicit the assumptions and judgments built into decision models or systems. Thus, those systems usually describing some distinctive sub-set of the organization's activities become increasingly rationalized and explicit, less and less intuitive. "Decision models" which once lay buried in management minds, and were describable at best by inference, are brought out in the open for everyone to examine.

Broader Decisions Possible

The characteristics of the computer are such that its use makes possible an enormous increase in the amount of information considered, in the range of alternatives explored, and in the speed of exploration in each decision situation. It should be possible, then, for management to do a much better job of co-ordinating various aspects of the firm's operations and assessing the impact of a decision, made with primary reference to one part, on other parts of the business. In other words, information technology should encourage an expansion of the arena within which individual decisions will be made toward the boundaries of the firm as a whole.

Vogt makes much the same point in his comments about the

International Shoe Company experience: the flow of factual, day-to-day information can be moved to higher and higher levels in the corporation, helping the large business to function like the small one in which all aspects of the business may more readily be carried in mind and correlated in the decision-making process.

Visibility, Speed, and a Shortened Planning Period

If business decisions can be made on the basis of an increasingly greater range of information, if the information can be highly quantified and processed at great speed, and if decisions are made on the basis of explicit assumptions and explicit rationale, then the decisions themselves will achieve a new visibility. In all organizations, it seems, there is a tendency to procrastinate, to put off decisions sometimes until most of the real alternatives have been washed away by events. Information technology may make many managers acutely uncomfortable by the spotlight it shines on the decision-making process. If a policy of "wait and see" is adopted, the decision is more likely to be explicit and its consequences are more subject to examination.

At the same time, the greatly increased speed with which information can be processed does make it possible to wait longer, yet "see" more. Incorporation of the computer into decision systems makes possible continuous and rapid feed-back of information from the environment to decision points (much as does an anti-aircraft fire control system). This permits rapid adjustment to new conditions, whether the new conditions are externally or internally generated. As a consequence, the planning period can be greatly shortened, and the risks inherent in forecasting can be further reduced. Grosz's example of rapid personnel scheduling may serve as an example, showing how the speed of the computer collapses the planning period necessary for the scheduling of both shift and maintenance work.

This ability to speed up the circulation of information should help to eliminate problems of internal time-lags in decision-making and the maladjustment and ineffective behavior which result from delays in communication. It is also possible, as McGregor indicates, that rapid dissemination of information may help to create common objectives in an organization. Common goals or purposes demand some supporting communication system which provides needed information at the right time and place for common action. This, he believes, is much more feasible now than in the past.

At the same time, information technology has a de-personalizing effect on the decision process. As McGregor puts it, instead of one person telling another what to do—which may raise questions about the individual's place in the organization, his status, and so on—the information is set up in the system in such a way that individuals receive cues from it which guide their behavior. These cues are impersonal, perhaps raising other issues and resentments against "having a machine for a boss."

Some Risks

The clarity introduced into the decision may be the greatest contribution offered by information technology; but, perversely, the involved systematization and the emphasis on quantitative types of information for which the extensive use of this technology calls may present one of its greatest dangers. We are all familiar with the uncritical attachment one often forms for ideas or systems one has developed. A great danger is that a decision system, once developed, will be used in a mechanical way without itself being subjected to systematic review and change as the reality it represents changes. Another important danger may result from overemphasis on the kind of information that can be made explicit in a quantitative sense. Much of the information important to business decisions results from qualitative and intuitive appraisals from the decision system. Thus, along with the decision opportunities presented to management, there are some risks against which management should guard.

In summary, information technology will affect decision-making in an organization by:

1. Quantifying information used for decision purposes;
2. Greatly broadening the scope of each decision and giving it new visibility;
3. Shortening the planning period;
4. Reducing the incidence of poor decisions caused by internal time lags in information flow;

5. Heightening the sense of common goals among managers through their sharing information;
6. De-personalizing decisions.

In addition, information technology, because of its imposingly objective nature, may introduce the risks of:

1. Treating qualitative judgments lightly;
2. Rigidifying the decision process.

THE IMPACT ON MANAGEMENT JOBS

Changes in the decision-making process such as those suggested above imply important changes in management structure, with the impact of information technology being felt by almost all managers in firms where these techniques are used extensively. The number of jobs at various levels, the content of many jobs, and the location in organizations of discretion and judgment, are all likely to be affected.* We will make some comments about the information technologists, functional research and planning jobs, lower- and middle-level supervisors, and top management.

The Information Technologists

Those people who are involved directly in applying the new skills and machines command immediate attention. At present, in American business, these individuals are scattered throughout the organizational structure. Their roles are ill defined, with some called on for minor occasional duties as special advisers, and others actively engaged in making major changes in the information systems that in turn strongly affect their fellow-managers. As might be expected in such an amorphous situation, the direction in which these jobs eventually will move in any given organization is, in good part, under the control of the people presently holding them.

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* Cf. Robert E. Slater, "Thinking Ahead: How Near Is the Automatic Office?" *Harvard Business Review,* March–April, 1958, pp. 160, 164, 166; and Carl H. Rush, Jr., "Implications of Electronic Data Processing for Industrial Research," *Proceedings Tenth Annual Meeting Industrial Relations Research Association, passim.*

Their own conceptions of the potential scope of information technology, as well as the imagination and insight of their own top-level managers, will bear importantly upon the eventual nature of their jobs.

Vogt and Hines argue strongly that the information technologist does not play a staff role but actually exercises line duties in performing his job. As Vogt states, the man in charge of these information systems cannot be placed off to one side of the organization but must be in the thick of things, from product development all the way through sales. Hines agrees with Vogt: Since the information technologists who build these systems are in large measure predetermining the decisions which other individuals in various departments must make, they cannot be regarded as staff people in the traditional sense. Grosz, on the other hand, argues that computer and systems analysis will have to remain a staff function because of a fundamental separation of interests and abilities between those people who carry out day-to-day operations and those who are engaged in developmental work. In his opinion, systems analysis and computer applications are basically developmental.

McGregor points out that each manager plays a variety of roles. The man we call a *line* manager sometimes functions as a line man, issuing commands and giving orders. But he also sometimes functions as a *staff* man, acting as an adviser to his boss, as a counselor to his subordinates, or as a consultant to his colleagues. Occasionally he investigates matters on his own. Each of these roles calls for a different kind of behavior on his part, and it is a mistake to persist in discussing him as though he were behaving in a simple and rigid fashion. The information technologist, too, plays many roles. At times he does research for and gives advice to top management. At other times he is laying out plans, devising systems, and setting up rules that other people have to follow.

Allowing for organization differences, however, the information technologist's job should eventually turn out to be a substantially unprogramed planning job based in the upper reaches of the firm's management structure.[*] (Actually, a hierarchy has apparently evolved already, within this area, separating the creative from the routine aspects of programing.) The computer and associated techniques make up a potentially important planning and coordinating tool in the hands of management. The information technologist—the man who designs and maintains this tool—would at the very minimum take leadership in organizing and systematizing the latest information available to the firm, in order to provide management with clear-cut decision alternatives and feedback about company operations. Given the organization's goals, he will find himself involved in devising sets of internal arrangements and rules to achieve those goals. He would be almost necessarily involved, as well, in plans for any restructuring of the organization and its decision rules that may be needed.

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[*] Slater and Rush, in the works previously cited, also forecast a prominent position for these people.

His relation to managers lower in the organization would seem to be that of prescriber of rules and planner. His relation to those responsible for innovation and commitment of resources is equally important and well-marked. He has at his command a combination of tools which help top management pre-test new ideas before making a commitment to them. This role is illustrated by the corporate laboratory developments at United Air Lines, described by Alberts.

These comments also suggest the probable merging of what appear to be two different ways by which information technology is coming into today's business structure. One is through the activities of the research group that builds models and tests proposals upon request; the other, through the group that redesigns and integrates the flow of information for decision-making systems in the firm. Whatever his line of entry, the information technologist's role in the organization seems likely to be an important one, with implications and contacts throughout the organization and with a base of operations near the top of the management structure.

FUNCTIONAL AND RESEARCH-PLANNING JOBS

At present, many of the larger firms have a range of jobs classified as research or planning, usually identified with one or another of the firm's functions, such as marketing, finance, personnel, production, and economic analysis. Information technology, with its powerful integrating effect, seems likely to move people in these functional research jobs closer together and, perhaps, to dampen their sense of departmental identity while moving them and their analytical work higher in the organization.

An example of this effect is found in the case of Atwood Vacuum Machine Company. Here, with the introduction of the RAMAC and the establishment of the planning department, staff functions in the other departments were abolished. Those jobs which were formerly scattered throughout the functional departments, and which involved investigating, planning, and co-ordinating for the individual functional managers, have been consolidated and placed in the planning department. Prior to the use of the RAMAC this was neither technically nor economically feasible as a way of handling the planning job.

Integration of these staff research jobs would seem to enlarge their scope while programing much of their routine content and trimming any overlap in research activity that may have been present. At the same time, one would expect an increase in the pressure for creative thinking, as the firm, through application of information technology, finds it economically and technically feasible to test a much larger range of new ideas. The development of research teams on a broader basis than has been the case in the past seems possible and likely. Analogously, the history of operations research has been one of bringing together a wide range of specialists with the objective of solving a specific set of problems. As the tools of information technology develop, the opportunities for further integrating the work of specialists on various business functions should increase. These specialists would also become the chief sources of raw data for general management planning. This role, in a high-speed information system, carries grave responsibility for identification and elimination of erroneous information before it is introduced into the system.

Closer to the operating level than research jobs are jobs like production scheduling, inventory control, and routine purchasing. The people in these jobs now perform a sort of translation task, taking general production or inventory decisions and turning them into specific parts of materials orders and detailed production schedules. Some low-level planning duties are combined with responsibility for a mass of detail. These jobs can often be programed right into the computer, relieving people in the organization of an often frustrating and sometimes almost impossible task. At the same time, some of those now performing these translation functions may be well fitted by experience and ability for jobs as information technologists. At any rate, the demand for personnel to do many of these traditional "production specialist" tasks should be curtailed drastically as information technology grows in importance.

A related though higher-level planning job is exemplified by Vogt's shoe buyer—a man who must estimate from his experience the numbers and kinds of shoes which consumers will buy in the next selling season and then set in motion the whole materials purchasing and production effort. A major part of his job is essentially statistical in nature. This part and some of his shoe scheduling activities have been programed, relieving him of the responsibility for handling them. One can foresee the day when the buyer's job will be still further programed, when much of what today is believed to be a matter of intuition and built-in judgment can be translated into programed analysis of sales and stock records.

All of this suggests greatly expanded staff activities in the upper management levels, with a reduction in certain planning jobs at the lower operating levels of management. The information technologists provide tools and systems, and specialists of various kinds contribute analytical categories for organizing information and leads to sources of data from inside and outside the organization. Much of the routine work associated with functional planning and research tasks is programed so that the computer, in effect, carries out this work. If these are valid implications of using information technology, then the jobs of high-level organizational planning and personnel management are due for greater emphasis, particularly during the transition period toward the new management structure. People in these jobs will have to think hard and work hard on the problems of sensibly and effectively arranging the co-operative activities of the specialists we see in the upper reaches of tomorrow's management structure.

Lower- and Middle-Level Supervisors

It is hard to avoid the conclusion that the use of information technology will lead to extensive programing of the daily tasks of present lower- and middle-level supervision and a reduction in the amount of discretion and judgment exercised at those levels.

The supervisor's job involves a number of activities which we call planning—such things as scheduling men to jobs, establishing priorities on accomplishment of jobs, determining some optimal sequence of operations for a given job, and so on. These activities, oriented toward work accomplishment, are much the same whether in manufacturing operations or in service operations. Planning of this kind in an organization of any size raises problems of co-ordination with others outside the area within which the supervisor has jurisdiction. In addition to planning activities, most supervisors spend a substantial amount of their time worrying about the problems of motivating employees, dealing with their personal problems, and clearly communicating the demands of the organization on them.

The integrative effects of information technology, the emphasis upon systematization and development of rules, and the increase in volume and speed of information circulation all lead to the conclusion that a great deal more programing of lower- and middle-level supervisor jobs is to be expected. We have experienced fifty or sixty years of gradual task programing of lower-level supervision under the older technology of Scientific Management. We should expect the impact of information technology to be greater at middle levels than at the lower levels, where a great deal of programing has already taken place.

Just what happens to the content of the middle-level supervisor's job is a matter of some dispute among those who have already had experience with this technology. Disagreement seems to stem from different experiences with the introduction of the new technology. Certainly the substitution of an electronic communication system for a paper one will have the effect of eliminating some low-level paper work activities. But it would be a mistake to assume that taking out paper work takes out only those activities that require manual or lower-level mental skills. The searching and scanning, the choosing and interpretation of information, make up a large part of the processes of decision-making and problem-solving. Yet these tasks are inevitably included in paper work activities to some degree and are tasks which can be and have been programed into computers.

Perhaps in its early applications the more obvious and routine kinds of information analysis and decision-making are programed into information systems. Examples of this would be the changes in the purchasing agent's job in Standard Oil of New Jersey's stores system and the changes in the shoe buyer's job at the International Shoe Company. But in these cases, the men who have done the initial systems planning see opportunities for further programing and for further development of rules which constrain and circumscribe the supervisor's activities.

Grosz characterizes information technology as the integration of small systems into larger ones. The people most affected by such integration are those who formerly co-ordinated these systems. As the integration proceeds, it is inevitable that the jobs of middle managers are affected.

The matter of whether this programing in any sense downgrades the middle-management job or makes it less interesting or less enjoyable raises questions about the kind of man who occupies the job, and about the ways work activities are reorganized and regrouped as old job structures are affected by information technology systems. One view is that, in the early stages of the use of information systems, the work changes consist mainly of bringing order and efficiency to a part of the job which was formerly very time-consuming and frustrating—searching for and ordering information. The job becomes more orderly and serene, and seems to concentrate on what we usually think of as real judgment and decision-making. Yet many people currently in these jobs may miss the "busy work" that formerly dominated the job content.

Whatever the sequence of programing in the content of these lower- and middle-level jobs and whatever the psychological reactions of the job incumbents, there will be some effect upon organization structure. The ranks of direct line supervision will be thinned, and the structure of organization should become somewhat flatter and perhaps have fewer departmental boundaries. Problems of inter-departmental co-ordination should diminish proportional to the development of systems which integrate information flows among these departments. And, finally, the content of the supervisor's job would seem to be gradually condensed toward one of transmitting information to and motivating those under him, and to responsibility for perception of patterns in his immediate environment which he should pass along as input information to the firm.

The middle manager may look more like a sergeant and less like a company commander than he did before. Dubin, looking at the impact of the new technology, says: "We are suggesting that the leadership functions in business organizations will be further centralized at top executive levels. In the middle reaches and supervisory levels of management, command activities will be emphasized and these will be standardized."[*]

TOP MANAGEMENT

What will happen to the jobs of top managers as information technology develops? It is relatively easy to establish what will *not* change. The individual firm's integrity and identity will not be affected, and therefore the organizational responsibility of top management will remain the same. The men in top positions will still hold full responsibility for the total accomplishment of the firm. But the suggestions outlined in earlier sections of this paper have implications for the top manager's role.

We have already noted that more comprehensive and more detailed information can be organized in one place and presented to top managers on a regular basis. The possibilities for greater integration of research and planning efforts flow basically from this fact. With these more unified efforts and with much more information at their disposal, top managers will be able—in fact, almost forced—to direct operations in a more detailed way, because selection of a "program" usually has detailed and specific implications. In other words, decentralization of business decisions has resulted in part from the sheer complexity of large business operations. The new techniques are means of dealing with this complexity, and so they make it possible to centralize many decisions. There are, of course, other reasons for decentralization that remain unaffected by the new techniques. But the "complexity" and "speed of reaction to new information" reasons have been powerful ones. Thus, we would expect top managers to be making more, and more detailed, decisions than at present.

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[*] Robert Dubin, *The World of Work* (Englewood Cliffs, N.J.: Prentice-Hall, 1958), p. 206.

At the same time, the whole top management effort is likely to be a more explicit one, with decisions more readily exposed to examination. As noted earlier, this development puts those with authority very much on the spot and may lead to more discerning judgments about the quality of the job being done at the top of the organization. If, as Clark Kerr has suggested, the way to high productivity is to put management "under maximum pressure to perform," then information technology should be a boon to our national living standards! Of course, sensing these implications, some top managers may shy away from these developments altogether—but only as long as their competitors let them get away with it.

If the manager must make more decisions more explicitly, he must also learn to use the new tools at his disposal effectively. We are not suggesting, of course, that he must be a universal technician; but he must understand the nature of the tools and of the intellectualized research processes associated with their use. It seems likely, then, that information technology will increase the demands on the intellectual capacity and range of top managers.

SUMMARY

Our discussion so far has suggested the following points:

1. Information technology leads to emphasis on quantification and makes it necessary for assumptions and judgments involved in the decision process to be explicit and thus subject to examination. The same may often be said about the decisions themselves.

2. The decision process will be improved by information technology because (a) more data can be considered, (b) greater speed of analysis is possible, (c) a greater range of alternatives can be explored, and (d) a more comprehensive view of a given decision's impact within the organization is possible.

3. The staff of top management seems likely to increase sharply

as information technology becomes more important. Using the new tools, a more integrated research and planning job can be done.

4. There will be relatively fewer lower- and middle-management jobs, and the content of these jobs will be affected. The effect will be the gradual programing of those parts of the job involving the planning of work activities; the jobs will take more of the characteristics of straight leadership and supervision. Information technology will affect jobs differentially, with some disappearing completely and with others being affected only slightly for a long period of time.

5. As information technology integrates decision-making and extends the decision area it also moves it higher in the organization, and thus has a centralizing effect. The speed with which this integration and centralizing occurs will probably depend upon the size of the company and upon the degree of systematizing which currently exists in company practices and structure.

6. The jobs of top managers will in some ways be made easier, since the new technology helps organize information and eliminate much guesswork. On balance, however, the pressures on top managers are likely to increase, since their actions will be subject to a more detailed check than ever before. The new tools which they have at their disposal may be intellectually quite taxing but, at the same time, exciting.

SOME PROBLEMS FOR MANAGEMENT

Projections of future development almost automatically lead to the questions, "What are the concurrent problems which will arise?" and "What should be done about them?" In this section of the paper we will examine some of the human and organizational problems suggested by the changes outlined earlier. Our interest here is in the traditional questions about meeting problems associated with change, securing the services of people, motivating, developing, and appraising them, working out appropriate compensation levels and structures, and gaining acceptance for new developments.

PROBLEMS OF CHANGEOVER

It is tempting to confine a speculative paper to analysis of some future state of equilibrium. This glosses over the pains of transition. The pains, however, are real and engrossing for management people, and the way they are handled can certainly affect the firm's longer-run position. We can at least identify the kinds of problems which will arise, even if we cannot promise happy solutions for all of them.

There are a host of problems traditionally associated with technological change. The content of some jobs is likely to be altered radically by the use of new techniques; other jobs are likely to be eliminated; new jobs can be expected to appear calling for skills and backgrounds which have not previously existed. This seems like old stuff, and it is. But the people involved are new. Those who previously reached comfortable conclusions about the social gains from technological change—the managers—are now the people affected. The problems are those of retraining, transferring, and—unfortunately—of lay-off or severance.

The impact will, of course, be substantially different in different firms and for different people. Where companies are operating in an expanding market, the number of middle managers needed may not decline much, and alert companies will finally find themselves relieved for a while of the strains and stresses concomitant with a constantly expanding supervisory force. But there will almost surely be other cases where new jobs will not be available for all the old managers. Particularly tragic cases, a few of which we have encountered, may develop where a department is virtually swept out from under a manager with long service whose value to the company lies chiefly in his knowledge of now obsolete procedures. His job mobility is often much less than that of the blue-collar or clerical workers he was supervising.

At the staff level, the job changes provide challenging opportunities for able people. Research opportunities of all kinds and jobs as information technologists may be expected to develop. Again, however, the new technology will affect most drastically those relatively routine staff jobs often filled by people whose capacity is limited.

There are no new prescriptions for these old problems. The traditional tendency to go easy on obsolescent managers, and perhaps carry them on the payroll until they retire, will on occasion be severely strained under the impact of information technology. And, unfortunately, the retraining problem may often be a sizable one, particularly where a high basic educational level is required for acquisition of real skill in the new environment. Because such transition problems can become severe if not anticipated and planned for, they should be brought to management's attention so that steps can be taken to ease the organization through the time of change.

The information technologist may, in turn, feel somewhat frustrated because of the necessity for putting some brakes on the rate of change. The logic of the systems which he develops may have to be compromised in the interest of gaining understanding and acceptance. In one company represented at the Seminar, human decision privileges have been purposely left in the system even though they could easily have been programed out. A print-out is made so that a person may look at a set of facts and then "make a decision" which could have been made inside the computer itself. Apparently, too, random access equipment is a useful device for buying acceptance for systems. When people can retrieve information from the system at will, they may feel the system is under their control and so is more acceptable. As an incidental point, it was noted that the installation of computers and other information processing techniques very often permits other procedural and organizational changes because these are believed to be part of the computer "package." The computer, in effect, becomes the vehicle for other desired changes.

Management, of course, has developed ways to deal with problems of change; and many companies can be expected to behave in a sophisticated way in dealing with resistance to information technology. Rush reports efforts to overcome resistance by early involvement in systems development of key men from those areas where the system will be applied. In building a team to develop the new system, an effort is made to use, as temporary systems analysts, people holding substantial positions in departments to be affected. These managers are told that they should know something about these techniques and that temporary developmental work is a good way of learning. At the same time, resistance to the introduction of the techniques is minimized.

Rush adds, however, that his company has by no means solved the problem. Occasionally sabotage appears. Operating divisions may make very unrealistic demands upon new systems as a means of expressing their hostility toward the new ideas. They will ask for impossible runs or make data changes at the very last minute. These systems, he notes, are quite vulnerable to this kind of hostility. Another area of vulnerability is that of data origination. The system is useless unless the basic information input is largely correct. Clerks sometimes test the computer by putting in the wrong digits. Certainly such tactics reflect a lack of acceptance in the organization.

Atwood has apparently had a minimum of difficulty in instituting the new system in his company. Several members of the Seminar commented on this, attributing his favorable experience to two things. First, his company is small. The kinds of estrangement and alienation which apparently can only too frequently develop in the large company are probably of minimal importance in a small organization. Second, his company has long pursued a policy of sharing information from top to bottom. (See Atwood's paper and his supplementary remarks, particularly concerning the Scanlon Plan as it is used in the Atwood Vacuum Machine Company.)

The large company representatives noted that theirs seems to be a substantially different problem. A local management, acting with autonomy, may reject a system worked out at a corporate staff level and institute one of their own, but one that later turns out to be inadequate in terms of the over-all goals of the company. Sometimes, in fact, individual managers pursue difference for its own sake. Information systems need a common language and common methodologies to be effective. Hence the possibility of individual choice is limited, in the last analysis, by technical requirements.

At any rate, problems of change will be sticky ones where they involve managers. Nevertheless, the problems can be identified and they have been met before. They may be among the toughest that management must face in introducing information technology. But they should be looked at fairly and squarely, so that their consequences for the organization as well as for individuals are minimized.

Personal Involvement of Middle Managers

The statement that middle-management jobs will be highly programed raises immediately the problems of keeping the middle managers interested in the organization's goals and motivated to do the kind of job that managers are expected to do. It seems to us, as it does to McGregor, that there are grounds for anticipating a cost to the organization in the form of diminished interest in corporate goals.

Look back, for example, at the impact of Taylorism or Scientific Management upon the job content and upon the motivation of the blue-collar worker. Factory jobs were programed by specialists using quantitative and systematic techniques. More and more, the planning, the creative aspects of these jobs were taken away from the production man, leaving him with only routine work to do. In many cases, these developments were accompanied by an attitude best characterized by the familiar phrase, "You do the work and I'll do the thinking around here." There is no doubt that the industrial engineering approach has made and continues to make a contribution to the efficient operation of production—but at considerable cost. Many observers have noted the alienation from work and from organizational goals produced, in their opinion, by the task programing which formed an essential part of Scientific Management. The literature is replete with examples of "sabotage" of systems by workers, and of virtual warfare between staff experts and the man in the shop over work methods, work standards, and systems of compensation.

Another set of experiences which leads us to worry about the problem of management involvement under task programing is the effort of first-line foremen to organize in the years immediately preceding the passage of the Taft-Hartley Act. It would be quite presumptuous to lay these organizing efforts strictly at the door of task programing, though personnel men and industrial engineers had succeeded in considerably reducing the scope of the foreman's job in many instances. There were other problems present, notably those related to pay. But formation of a union is an extreme step for managers. Certainly it raises doubts about the identification with corporate goals of foremen who seek to unionize "against management."

Is the effect of information technology upon management jobs analogous to the impact of Scientific Management? In cases where information systems involve prescription of decision rules for men who formerly made up their own, the analogy seems clear and unmistakable. Nonetheless, several men insisted in the Seminar that the impact of information technology, in the main, resembles, not Scientific Management, but factory automation. By this they meant that the effect is not to de-skill jobs but to transfer the lower skills to machines, leaving the high-skill components to be performed by fewer men. This is an appealing idea, but it would seem wise to be careful and not to mistake introductory phases of the new system for the net effect of a complete application of information technology.

It is true that electronic data processing very often replaces some drudgery previously performed by clerks. The systems which staff men in this area envision, however, involve preplanning of interrelated activities within the firm. The result is the establishment of decision rules for men who formerly made up their own. It seems an inescapable conclusion that information technology, in at least some of its forms, involves some people prescribing rules for other people's behavior—rules which were formerly formulated by the second group for themselves.

This is an issue of deep interest and importance because many social scientists and, more recently, some business managers, have concluded that task programing affects motivation adversely. Where a man has a large measure of discretion in setting up the rules for his own job and in making his own choices, the argument runs, his motivation is high and his ingenuity and creativity are stimulated. Where his task is routine and small in scope, and he feels himself to be pretty much under the control of others who set decision rules for him, he has little interest, and he very often exhibits hostility and indifference. Occasionally someone points out the dangers of accepting this argument too wholeheartedly.*

Whether our experience with Scientific Management and unionization of foremen will be helpful in dealing with the change to information technology depends upon whether we really know what we have learned. The attempts to unravel and re-do, which were characteristic of the human-relations-in-industry movement, deserve careful study, as they may offer some leads for dealing with the impact of information technology on management. Experiences with such diverse developments as job enlargement, the Scanlon Plan, personnel rotation into special projects, and, of course, decentralization in management, suggest ways to deal with the alienation problem as well as, perhaps, limitations of the usefulness of information technology.

COMPENSATION

The compensation of managers is a problem which has never been too clearly resolved in present-day organizations, particularly from the standpoint of the student of management practice. Certainly, the number of recorded studies that provide some insight into management policy and practice on this subject is extremely small. We know that wage and salary systems exist, but we also know that a common principle is that of compensating a man and not a job at the management level.

It seems to be true, however, that position evaluation has made its greatest inroads at the lower levels of management, where the content of the management task is most programed, and that the tradition of strictly individualized compensation, with large proportions of bonus for company or division performance, holds greatest sway at the top, unprogramed levels. This one bit of evidence suggests that compensational practices will move increasingly toward systematization and formalization at the middle-management levels.

What will happen at the top levels is certainly more complicated. Some confusion and even chaos may accompany the appearance of new jobs and the growth of emphasis on innovation and creativity—this has been the case in the advertising business.

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* Robert N. McMurry, "The Case for Benevolent Autocracy," *Harvard Business Review*, January–February, 1958, p. 82.

We expect labor market forces to be much more clear-cut than in the past, since the proportion of professionals with readily transferable skills seems sure to rise. In fact, with increased emphasis on information technology and research, a real up-ending of salary structures seems likely to occur; and the advantage in salary of line executives over staff experts may disappear or at least be greatly diminished. Particularly during the transition, the salaries of those people who have the kinds of skills involved in programing, in model-building, and in creative thinking should rise rapidly as market forces overpower the forces of organizational tradition.

Some contradictory forces might also be at work. We have suggested earlier the tendency to integrate erstwhile separate functions involving a variety of professional specialists. This might imply team compensation or group bonus arrangements. In the thinking of some people, at least, this would run head-on into another theory of incentives based on the notion of compensating the creative individual more highly than his less creative colleague. It would seem that there will be a desperate need for some effective research on the part of behavioral scientists to help on this point. We really do not have any good clear answers on matters of creativity, individual incentive, and integrated research effort.

Finally, we might anticipate that the pattern of status symbols, of "non-monetary compensation," may alter radically. In place of deep carpets, modern furniture, the uncluttered desk, and the grey flannel suit, we might even find a growing emphasis upon the paraphernalia near and dear to the academic—or at least the scientific—heart. New patterns of non-monetary compensation and a more variable structure of fringe benefits may be called for, and a tradition-bound organization may have real difficulty learning to live with this greater internal variety. But, here again, we are caught with little knowledge. What does the kind of man we are looking for want in a job? Money, to be sure. Studies could, and should, be made concerning the mobility of scientists among jobs paying different rates. We would be surprised to learn that they did not behave substantially as their non-scientific brethren would in responding to the lure of a higher salary. But we know also that people, once having achieved a sort of minimum desirable salary, then respond to other patterns of attractions. About these we have much to learn.

Problems of Management Development

One area where it seems reasonable to expect substantial change is that of management training or development. The earlier statements about the structure and nature of management jobs suggest an extravagant increase in specialization. And specialization calls severely into question the traditional management practice of using work experience at successive levels in the management hierarchy as the basic executive training device. If the planning content of command jobs down the line is diluted, these jobs will not develop or test the skills needed in the firm's upper echelons of command. It may well be that executive training in the future will increasingly combine some years of service in a junior command position with jobs as assistant to a senior executive and to a senior staff man or a group of such men. In addition, the university or the firm's training counterpart seems likely to play an increasing role in executive development, since familiarity with a number of fairly specific and teachable bodies of knowledge will be of increasing importance to executives.

The need for increasing numbers of high-level, high-powered staff people is also likely to pose some new problems of management development. These staff people have skills of the intellect as their basic resource, rather than the kind of skill and wisdom derived from experience that is so vital in top management command positions. They are useful to the firm for what they know and for what they can conceptualize, rather than for what they can carry out. They will need familiarity, to be sure, with the internal procedures and problems of their firm; but too great a familiarity may be inhibiting. What they need to see is variety and what they need to understand is the environment of their firm and the methods available to gauge environmental change.

All of this suggests some limitation on the idea of development within a firm, with emphasis on promotion from within. Perhaps firms, at least all but the largest, will have to consider the market place as a management developer more than has been their custom. Thus a tour of duty in a management consulting firm or a research-oriented business school may be of greater benefit in the career of a top staff man than the same amount of time spent at one of the company's plants. This kind of development-through-mobility, of course, will cause tensions in those organizations where traditionally a newcomer is a man without his twenty-year pin. It also implies that the burden of training and retraining for the new staff jobs is likely to fall more heavily on the man than upon his immediate employer—though, of course, over a period of time, it is employers as a group that provide the environment and opportunities for training.[*]

THE DECENTRALIZATION ISSUE

We may summarize here the comments made at various points in this paper about the widely discussed subject of decentralization of decision-making within management. Our argument is that use of the high-speed computer and associated techniques, "information technology," will be a force for centralization of decision-making, along with an expanded staff at the top levels and fewer jobs, with more highly programed content, at lower levels in the management hierarchy. Many of the problems that we have discussed stem directly from this judgment.

Some other observers agree with this conclusion:

> Actually, decentralization [of operations in a large company] will, in many cases, represent a backward step, and this retrogression is made necessary for only one reason. Centralized operations have failed in practical operation because of inadequate data processing and communication within the organization. An electronic computer will completely change this situation.[†]
>
> Though physically decentralized, the control of operations will be, as previously indicated, concentrated in a central location to an even greater degree than is possible today. It seems highly probable that technical developments in communications will restore the concept of centralized management control.[‡]
>
> Further down the line, though, decision-making can easily be taken over by the computer. Centralization of decisions, there-

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[*] Slater and Rush, in the works previously cited, discuss the future problems of management development in much the same terms as they are presented here.

[†] William D. Bell, *A Management Guide to Electronic Computers* (New York: McGraw-Hill, 1957), p. 241.

[‡] *The Coming Revolution in Industrial Relations 1955–1975* (New York: Industrial Relations Newsletter, 1955), p. 35.

> fore, once again becomes possible. It isn't likely that top management, with such a tool, will forego the chance to centralize merely to satisfy an outmoded philosophy of decentralization that no longer meets the needs of the company.*

Still others make a similar forecast, couched in more cautious terms.† Those who hedge this issue usually do so by prophesying centralization of planning and control, but decentralization of operations.

However, there are those who argue that the new technology further strengthens the case for decentralization of decision-making. The decentralization argument typically does not rest on the notion that the techniques we are discussing will not be widely used—quite the contrary.‡ One will find computers, so this argument goes, at all levels in the organization; so that, through these techniques and equipment, managers far down the line will at last be able to assemble the information needed to carry out a policy of decentralization effectively. Knowing all the relevant information that can be quantified and processed and having the ability to explore quickly the impact of his decision on others in the organization, the man on the spot, who has a "feel" for the situation, can then make a better decision than anyone else in the organization.

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* Richard L. Waddell, "Communications: Pushbutton Control," *Challenge,* IV (Nos. 11–12), 14.

† "New Tools Will Change the President's Job," *Dun's Review and Modern Industry,* LXVIII, No. 4 (Oct., 1956), 78, 90–94.

‡ For example, Harold F. Smiddy, in developing the decentralization thesis, states, "Don't get me wrong! These new tools—these mathematical models of the 'whole business' complex, and these transistorized computers to store up and then to manipulate literally tens of thousands of simultaneous business variables—are here. And they do work. They are getting better, and they will continue to do so at a fantastically accelerating pace.

"These new tools and devices memorize information. And they will use it, on an increasingly self-monitoring and self-adjusting basis, to 'make decisions' of certain repetitive types automatically; decisions which have stretched and puzzled you to make mentally for most of your business careers" ("Managerial Decision-Making," *Advanced Management,* XXIII, No. 11 [Nov., 1958], 10).

He continues, "And, I suggest, they will increasingly do this with the aid of simulators and computers which are themselves—like erasers or adding machines—increasingly decentralized both physically and in constituent design for direct use at or near the local workplace; connected together by circuitry to simulate the *over-all* business as it actually exists as a living organism—by the synthesis of its separate parts from the parts to the whole, not be mere centralized subdivision from some master-mind down" (*loc. cit.,* p. 11).

Leaving aside the economic problem of justifying the cost of many small computer and analysis groupings, this line of argument neglects the need for co-ordination of decisions in many cases, particularly since such co-ordination is often a matter of resolving conflicting interests of subgroups in organizations. In other words, when local "feel" for information that defies quantification is of dominant importance, and when parts of an organization are not closely related, decentralization would hardly be changed by use of information technology. On the other hand, when information can be quantified and decision rules evolved, and units in an organization are interdependent,[*] more central location of decision-making seems likely.

In any analysis of this sort it is wise to consider that, unless a certain amount of interdependence exists, it is doubtful that an organizational entity exists. Even in the decentralized corporation of today, the process of internal capital rationing points up interdivisional dependence.

Often a policy of decentralization has been pursued because of the overwhelming complexity of large business operations and the need to react rapidly to new information as it becomes available. While business may be expected to become ever more complex, the new developments should deal with the information problem in heroic fashion. Under these pressures, significant changes in organization structure seem inevitable. Seminar participants were perhaps in closer agreement on this point than on any other discussed: that the pressures for change generated by the introduction of the new technology are in the direction of centralization of decision-making, of control, and of co-ordination. The reader may confirm this observation by reading the various papers presented.

NEEDED RESEARCH

The papers and the discussion coming out of this Seminar have combined speculation, current practice, reasoned forecasts, and some general reflections on the impact of the new information processing and analysis systems upon the structure of business. Particularly, we have discussed the impact upon the structure of management, since the processing of information and the analysis of information are integral parts of decision-making, which in turn is regarded as a chief function of management. One of the products of the Seminar has been understanding of what we do not know and what we need to know, as students and as managers, before we can have a clear idea of the road we are following and an insight into how management can best use the new tools it has at its command.

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[*] It seems possible to determine rationally whether interdependence of a crucial sort exists. This kind of careful analysis in the vital decision area of product pricing has been demonstrated by Jack Hirshleifer, "On the Economics of Transfer Pricing," *Journal of Business,* XXIX, No. 3 (July, 1956), 172–84.

Decision-Making in Groups

Various participants in the Seminar indicated the importance of the use of groups in planning information systems. We have indicated in our paper that we would expect top-level decision-making to become more a group affair and less an individual matter. That high-level decision-making groups already exist is a matter of record; that they should become more important is a matter of reasoned expectation. We need to know more about how and under what circumstances they work best.

The small group theorists have only scratched the surface of understanding group decision-making processes. This is not a criticism of their efforts but an appraisal of the stage and direction of their work.

The directions taken by their research will doubtlessly continue to vary widely. Some of this research will be of direct and immediate interest to those who administer, and some of only indirect and remote interest. In particular, an effort should be made to push forward the research of the group theorists into the area of group-computer systems.

If the academic environment does not produce such research efforts, we can be sure that business practice will continue slowly, but surely, to advance the understanding of the use of groups and computers. With the development in recent years of an interest among large business firms in establishing their own social science research staffs, we may see the research efforts taken over in part by business itself.

RESEARCH ON COMPUTERS

This kind of research is being carried out, by a number of very competent people, in various areas and at various levels. Some of it relates to problems of hardware—of the difficult problems of producing equipment which will do the kinds of tasks necessary to maximum exploitation of this tool. Some of it goes on at the program development level. These two areas are obviously closely interrelated. Above all, the business community is interested in understanding the adaptation of business organizational structure and practice to use of the new computers *and vice versa.* Here again the problems are interrelated, and the results of research in different areas must be fed back and forth to permit a balanced and rapid development.

As we became aware in the Seminar, there is not always complete agreement concerning who should be doing what technical research. Some people in business believe that the computer manufacturers have not developed equipment with the capacity and the adaptability to handle business problems as these presently exist. Others in business, with substantial experience behind them, are inclined to sympathize with the manufacturer, pointing out that the development process necessarily must be one in which user and manufacturer help one another. The manufacturer has basic hardware responsibility, but the cues indicating directions in which he should move, how far he should move, and so on, must come from the user.

The development of the most general kinds of problem-solving programs, which are the programs which offer greatest promise for business use, probably must be carried out by non-business research groups, or at least by research groups which lie outside the business firm. This subject was discussed at some length in the Seminar. If the research efforts of a team inside a company culminate in a highly specific program, its adaptability to the problems of other companies is limited. Any problems of competitive piracy are minimal. But a very general program might be useful in many companies. That company which chose to develop it would thereby pick up the developmental costs for its competitors. Yet, the social (and private) benefits of the computer, as Simon points out in his remarks, can be realized to the maximum only if such general programs are developed. The universities or the government, as in the case of much other basic research, are the logical units to undertake research on developments of general applicability.

Organizational Changes Brought about by Information Technology

The issues considered by this Seminar have led to a number of conjectures on changes which may develop in organizational structure and some observations on changes which have already appeared. The constant watching and testing for effects, that will give us some feeling for the direction in which we are moving, should be carried out on a wide enough basis so that the experiences of individual firms, that might be influenced by their own peculiar conditions, will not be misleading. The experiences of Standard Oil of New Jersey, for example, may be indicative of the general structural changes we could anticipate as information technology is applied in the large, decentralized firm. But their experiences need to be checked against those of other firms of the same character. The experiences of the large firm need to be compared with those of the small. The service industry's experiences need to be compared with those of manufacturing, the international firm's with those of the local, and so on.

Research on the growth and development of an institution can be carried on most effectively by someone who stands in the most general relationship to this institution. Groups within the business firm are at a disadvantage here, although the trade association or groups like the American Management Association or the National Industrial Conference Board could undertake such research. However, this research seems quite a suitable undertaking for a university, particularly a school of business faculty. The schools of business have been urged on many occasions to pioneer by indicating the direction in which business practice is moving, will move, or should move. Such leadership requires a program of continuous research. Research on the organizational changes following the introduction of information technology, therefore, seems appropriate for a business school.

Training Managers

Over the last fifty years men in business appear to have swung from the belief that managers should be trained exclusively by working in a company to the belief that they should be prepared initially by a university background. Agreement is far from complete on this, of course, but the practices of many business firms suggest the value placed upon a college training.

But there is little agreement on the kind of college background the individual should have. A great diversity of training is possible and, increasingly, is sought by business firms. If information technology makes a fundamental change in the structure of business management, it is reasonable to expect that this would feed back into and change the problems of training young men for business and, perhaps, of retraining experienced business executives to meet changed conditions.

Once again the problem is general enough so that schools of business, and universities generally, should be active in seeking answers. Of course, the individual firm will also have to face special training problems in the short run, particularly at the early stages of introducing information technology.

At present, we have no clear picture of future training needs. One point of view, growing in popularity, is that the important training problem of years to come will not be training young people prior to their entry into occupational roles, but helping people in the middle of their careers, as the body of knowledge grows generally and in the area of their specialty.* The problem of the rapid obsolescence of technically trained people has already made itself apparent in American business, as well as allied problems such as those involving compensation. The training implications of this problem have not been explored extensively. Research is vitally needed here.

Impact on Personnel Practices

At various points, in this paper and in others presented here, there has been speculation about the kinds of changes which will appear in traditional personnel policies and practices. We have already singled out the area of training as worthy of special note. Training problems are already acute in companies which have moved rapidly in expanding their efforts in information technology. But there are at least two other very important areas which can be expected to change.

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* See, for example, Margaret Mead, "Thinking Ahead: Why Is Education Obsolete?" *Harvard Business Review,* XXXVI (November–December, 1958).

One relates to compensation of executives. We have already noted that changes in the traditional conception of organization, perhaps minimizing the distinction between line and staff and between planner and doer at certain levels, together with the specter of obsolescence of technical knowledge, may make traditional compensation practices unworkable. What will replace them is difficult to forecast at the moment, since we have no accurate picture yet of the kinds of organizational changes which will ultimately emerge. In conjunction with studies of change in organizations, research will clearly be called for on corresponding changes in administrative practices. One of the most important is payment of compensation in an amount and in a manner that will motivate people to produce and to remain with the organization.

Another problem area important, both to all individuals working within an organization and to the organization itself, is the appraisal of the individual's contribution. The appraisal of performance is intimately related to compensation but is also a matter of general concern to the organization because of the need to find, as early as possible, the leaders of tomorrow. With an upheaval in the conception of what kinds of knowledge are important and with the probable change in the way men are trained and move through the firm during their useful work life, corresponding changes should be expected in the way information about individual performances is gathered and analyzed. The conflicting value schemes of the scientific organization and the hierarchical form of organization which have characterized business for a number of years may present problems of growing importance for individual appraisal. This conflict, already a matter of some years' experience in those firms having extensive research and development groups, is much better understood than it was even a decade ago. Research on the problems and practices of business research groups may assume added relevance for the whole organization in the years ahead.

Information technology is an important and growing part of modern business practice. It will doubtless make its mark on management organization and bring in its train difficult organizational problems as well as brilliant technical achievements. Some of these developments are already apparent and have been pointed up in the Seminar discussion reported here. Others are as yet obscure. Careful observation and research will enable us to identify major developments at an early stage and, with knowledge as our servant, we shall be able to use the new technology to our general advantage.

PART II

Technical Developments and Their Use by Management

"We shall be concerned with the capabilities of computers to perform tasks now performed by human beings and with the conditions that will determine the division of labor between computers and human beings in business and other organizations."

WHAT HAVE COMPUTERS TO DO WITH MANAGEMENT?

By

Herbert A. Simon and Allen Newell[*]

By the common ruts of free association, "computer" suggests "automation," and "automation" suggests "technological unemployment." Where computers are involved, the last phrase takes on added piquancy, because some have suggested (the authors among them) that computers may be able to do not only the work of clerks, but even the work of managers.[†] One purpose of this paper is to evaluate that claim and its implications.

But to focus on the issue of displacement of human beings by machines is quite misleading, and it will be well to dispose of that issue at the very beginning. Whether all, most, or few of the persons who want gainful employment will be employed depends basically upon the machinery of society—economic, social, and political arrangements—not on the machinery of the factory or office. Full employment is about as easy, or as difficult, to attain in a society that gives each worker ten thousand dollars of capital equipment and ten horsepower as in a society that makes him produce with his bare hands and unaided muscles. This would not be true, of course, if human wants were satiable and the boundary between work and leisure fixed. Fortunately, neither of these conditions holds.

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[†] See Harold J. Leavitt and Thomas L. Whisler, "Management in the 1980's," *Harvard Business Review,* XXXVI, No. 6 (November–December, 1958), 41–48; and Herbert A. Simon and Allen Newell, "Heuristic Problem Solving: The Next Advance in Operations Research, VI (January–February, 1958), 1–10.

We shall not discuss, therefore, whether computers will cause unemployment for human beings. We shall be concerned with the capabilities of computers to perform tasks now performed by human beings and with the conditions that will determine the division of labor between computers and human beings in business and other organizations.

TECHNOLOGICAL FEASIBILITY AND ECONOMIC EFFICIENCY

There is a difference between the capabilities of computers and their prospective use which is based on the distinction between feasibility and efficiency. Thus, for reasons of efficiency, not feasibility, the nuclear reactor has not (at least not yet) revolutionized the power industry. If it ever does, it will be because coal has become more expensive and atomic power cheaper.

Technological feasibility, then, is a necessary but not a sufficient condition for use. The world is full of technical possibilities that are not worth exploiting. We had the promise of "free energy" from the sun and the tides long before the nuclear reactor was devised. Unhappily (as with nuclear energy) only the fuel was free; expensive capital structures were required to collect and apply the energy, so that "expensive" coal still remains, in general, a cheap source of energy.

There are similar subtleties in the evaluation of computers. Their nature will become clearer after we have completed a survey of the kinds of tasks computers might perform.

What Is a Digital Computer?

Laymen, and even most computer specialists, think of the digital computer as a stupid device which, when instructed in detail, can do arithmetic extremely rapidly. The following description by our colleague, Alan Perlis, well represents this point of view:*

> A digital computer works with numbers in their numerical form. . . . The real advantage of digital computers is not their precision but their being automatic and very fast. The kind to which I refer are those which do a sequence of [arithmetic] operations without requiring human monitoring. The machine carries out this sequence by following an instruction pattern called a "program." By one means or another this program is inserted in the computer and then the computer, with magnificent insensitivity to the significance of the pattern, follows it step by step.

Since this kind of description of the computer prevails at the present time, and since we dissent from it in several respects that are crucially important to our discussion, we shall have to set forth, at some length, an alternative.

Is the Digital Computer Numerical? A digital computer is a device for manipulating *symbols.* It is only an accident of history that the symbols usually manipulated in computers at the present time are numbers rather than alphabetic symbols or some other kind.

Of course, if we open the lid of a computer and look inside, we do not see numbers or any other symbols. At best, we "see" magnetic patterns or electric charges on a tape, in a gird of tiny ferrite "doughnuts," on a metal drum, on the surface of a glass tube, or what not. They could just as well be pencil marks on a piece of paper, except that we do not know how to write or erase such marks rapidly enough for the purpose at hand (the time intervals we allow in a computer for writing, reading, or erasing symbols are of the order of thousandths or even millionths of a second—milliseconds and microseconds).

Now, a pencil mark can represent a number or a letter—all depends on its shape and the conventions we have previously established in the form of "alphabets" or symbols. Purely by convention, "3" is a symbol from the alphabet of numbers, "E" a symbol from the alphabet of letters. Any physical device that will allow us to record such symbols (or an equivalent set—e.g., holes in a punched card or the dots and dashes of the telegraph) can be used as a component in an information processing system—for example, in a digital computer. A device that can be used to manipulate numerical symbols can almost always be adapted to manipulating alphabetic symbols, and vice versa.

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* Alan J. Perlis, "A Tool for the Mind," *Carnegie Alumnus,* XLIV (December, 1958), 4.

Thus, whether the computer's symbols are numerical or verbal depends on our (and its) use of them. If we establish, by convention, a literal alphabet, communicate to an appropriately programed computer the sentence "John loves Mary," and ask the computer to put the sentence in the passive voice, then we will expect it to reply, "Mary is loved by John." If it fails to do so, the defect lies in its program and not in any preference it has for arithmetic over grammar.*

The computers that are manufactured for general commercial and scientific use contain a component, the arithmetic unit, that enables them to perform additions and multiplications with great rapidity by doing them substantially in parallel, the way an electric desk calculator does them, rather than column-by-column using a built-in addition and multiplication table, the way a human being does.

If we wanted a computer that would live a more ordinary life, instead of devoting all its time to doing arithmetic, we could simply omit the expensive machinery required for rapid parallel arithmetic operations. Such a computer could still do arithmetic either by being given access to and control over another computer (its "desk calculator"), or—if speed were not important—by being given the tables of sums and products and a program for using them to add and multiply.

Again, this possibility is not fanciful or hypothetical, for we have discussed the design of a computer, to do non-numerical information processing, that would not have a specialized arithmetic unit.†
Preoccupation with arithmetic is an accidental and not an essential property of current computers, and non-numerical computation

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* The example is not hypothetical. Computer programs are being written that carry out just such syntactical tasks as this one.

† J. C. Shaw, A. Newell, H. A. Simon, and T. O. Ellis, "A Command Structure for Complex Information Processing," *Proceedings of the 1958 Western Joint Computer Conference*. Forthcoming.

will, over time, come to occupy a much larger place in the scheme of things.

Can a Computer only Follow Instructions? The usual answer to this question is the assertion that a computer can do only what it is told to do. This is well expressed in a passage by M. V. Wilkes, a prominent British authority on computers:

> An automatic calculating machine thus provides a mechanization of a human computer plus a desk calculating machine—although, of course, it is only the computer's ability to obey rules which is mechanized, not his intelligence.*

This answer seems to give great comfort to people who are worried about the computer's challenge to the uniqueness of man—the same challenge raised, a century ago, by Darwinism, and, four centuries ago, by the Copernican picture of the universe.

We do not deny that most men, including ourselves, find a comfort that is hard to relinquish in the idea that man is unique. But most of us also find it difficult to take comfort from chimerae—we accept Darwin and we accept Copernicus on the evidence, however uncomfortable their doctrines. We must ask, therefore, whether it is correct to assert that computers will always imitate and never create.

The answer, as in all such cases, depends critically on the definitions of the terms. A computer is a determinate system whose behavior at the next moment is the inevitable consequence of the state of its memory at the present moment together with the stimuli that impinge on it (its "inputs"). If we design and build a computer and determine its entire history of inputs (at least back to the moment when its memory was last completely erased), then we have determined its behavior for the next moment of time. Its path is as inexorable as the paths of the planets.† Thus, if to be determinate were to be unable to create, computers could not create.

But if we apply the same definition to man, it may well be that he is also a determinate system. At least there is a large school of thought in modern times that believes that the behavior of a man, at the next moment, is completely determined by his genes and the environment to which he has been exposed since conception—that if we only knew the initial conditions and the differential equations, we could predict his behavior also.

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* M. V. Wilkes, *Automatic Digital Computers* (New York: Wiley, 1956), p. 2.

† Formally, the behavior of a computer can be described completely, for any possible history of inputs, by a system of difference equations in exactly the same way as the behavior of a planetary system can be described by a system of differential equations.

Some have sought to locate man's freedom in an inextinguishable core of randomness. It has even become fashionable to associate this randomness with the uncertainty principle of modern quantum mechanics. But it takes only a cheap trick to make the behavior of a computer depend on a random element—we can easily program a random number generator. And if a sophisticate objects that the numbers formed by such a generator are not "really" random, we can hook the computer to a Geiger counter, which will introduce genuine quantum randomness into it.

It appears that the questions of freedom and creativity are not likely to be answered by searching for fundamental distinctions between the structures of men and machines. It will be more profitable to try a simpler and more empirical question. Let us define creativity by pointing to some unquestionably distinguished creative products: a Beethoven symphony, the proof of the fundamental theorem of algebra, *Crime and Punishment*, the Copernican hypothesis, a Morphy chess game, or a Cezanne landscape. Then we may ask whether a computer could, in principle or in fact, produce equal creations (not copy them, of course), or whether the creativity would always have to reside in the programer.

It is easy to answer one question of fact. No computer up to the present time has performed a creative act that comes even close to one of these. But in so far as we understand what *processes* are involved in creativity, none of these processes appear to lie beyond the reach of computers.*

To create is to produce effective surprise (and the surprise may affect the creator as well as his audience). The creative person finds rare treasures in enormous mazes by learning to thread his way through these mazes with a relatively small waste of time in blind alleys. He surprises himself because he sometimes picks up cues without being at all sure where they will lead; and he surprises others—who often do not even see the cues that are brightly visible to him, and hence do not understand how he finds the right alleys and avoids the blind ones.

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* A. Newell, J. C. Shaw, and H. A. Simon, *The Processes of Creative Thinking*, P-1320, The RAND Corporation, September 16, 1958. To be published in University of Colorado Symposium on Creativity, 1958. Forthcoming.

Now we cannot expect a computer (or a man) to create—to produce effective surprise—if the program it is following is a simple one, well known to us, so that we can predict exactly the kind of thing it will do. Even if it can compute numbers that we could not compute because we do arithmetic so slowly, we do not think of it as creative: it is only doing what it was programed to do.

Suppose, however, that a computer contains a very large program that has been introduced into it over a long period of time by a number of different programers working independently. Suppose that the computer has had access to a rich environment of inputs which it has been able to "perceive" and select from. Suppose—and this is critical—that it is able to make its next step conditional on what it has seen and what it has found, and that it is even able to modify its own program (determinately, of course, on the basis of higher-level programs) on the basis of past experience, so that it can behave more effectively in the future. At some point, as the complexity of its behavior increases, it may reach a level of richness that produces effective surprise. At that point we shall have to acknowledge that it is creative or we shall have to change our definition of creativity.

To summarize this long excursion: a computer can do only what its program tells it to do; but the latter can depend, in a highly conditional matter, on the whole previous environment to which the computer has been exposed. Whether human beings have any greater freedom than this is debatable, although we are inclined to think they do not. Whether they do or not, it does not appear that greater freedom is needed in order for an information processing system to learn or to create.

The Conditional Transfer. Our discussion of creativity suggests that the most important single characteristic of a digital computer is its capacity to make its processing conditional on the information it receives. When this capacity is present, following a program is no longer the same as behaving blindly or mechanistically.

The capacity to respond conditionally to symbols requires, in turn, only a simple capacity to determine whether two symbols are identical or different. We can illustrate this by the example of a single program to govern the behavior of a driver at an intersection with stop lights. We associate with a red light the internal symbol "red," and with a green light, "green." The program then reads: compare the perceived symbol with "green": if they are identical, proceed across the intersection; if they are different, stop.

All more complex discriminations—e.g., recognizing a picture of the Taj Mahal—can be built up from sequences of such simple yes–no discriminations. In the same way, any complex sequence of responses—e.g., uttering an English sentence—can be built up from simple sequences of yes–no responses.

All digital computers have one or more conditional transfer operations (sometimes called "branch" or "jump" operations) in their instruction codes. These operations were originally devised (one hundred years ago, by Charles Babbage) to permit the computer to repeat the same arithmetic operations on a whole sequence of data, and then to go on to a new operation when the first operations had been completed for all the data. To do this the computer had to be able to sense when it had reached the end of the sequence, and to respond differently after processing the last item than it had after processing the previous items.

From this first modest application, conditional transfer operations have increased in importance until, in some recent computer programs for solving complex problems and simulating human higher mental processes, comparisons of symbols for identity ("tests") and transfers conditional on the outcomes of the tests become the dominant features of the process.

Computer Anatomy. We may summarize the above discussion by noting that, in its essentials, the digital computer is remarkably simple. There is a *memory* capable of holding symbols, and there are devices for writing symbols in memory, reading memory, and erasing. There is a *central processing unit* that need be capable only of comparing symbols for identity (although in current computers it can also perform rapid arithmetic). There is a *control unit* capable of reading and executing a small repertory of instructions ("compare," "read," "write," "transfer if identical," and the like). Any device having these components can be used as a general-purpose computer, although its speed of operation will depend critically, of course, on the physical nature and interconnection of the components.

What Do People Do in Organizations?

Let us leave the topic of computers for the moment, and turn to the other side of the equation: the nature of the tasks that are performed in organizations. We will leave physical labor out of account and consider only "mental" tasks—including in this category, however, pushing a pencil across a piece of paper and operating a bookkeeping machine.

It will be convenient to speak of three types of mental activities: clerical tasks, programed problem solving, and nonprogramed problem solving. Nothing very fundamental is intended by the classification, nor can sharp lines be drawn between the several categories; but tasks change in various ways as we move from the most routine to the least routine end of the continuum, and it will be useful to have terms to denote three points on the scale.

In this terminology, "clerical" means highly routine and usually repetitive. "Programed" means well defined, relatively systematic, and somewhat repetitive. "Nonprogramed" means relatively unstructured, novel, and even creative.*

Clerical Tasks. Certain sequences of clerical tasks—e.g., those involved in preparing a payroll—have been so completely analyzed that computer programs have been written for them. A moment's reflection on the nature of these programs shows that they involve reading numerical and alphabetical information, transferring information from one document or record to another (including sorting and collating), and performing simple arithmetic calculations. Moderate variations in the information content among documents (e.g., in the list of payroll deductions) are handled by relatively simple conditional transfers.

Somewhat more interesting are clerical tasks that have *not* generally been automated. Transcribing orally transmitted messages, reading handwriting, handling incoming correspondence

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* For additional discussion see James G. March and Herbert A. Simon, *Organizations* (New York: Wiley, 1958), chaps. 6 and 7.

(even if it is typewritten), filing and retrieving information in correspondence files, and answering miscellaneous inquiries are typical examples of tasks that are always or usually handled by human beings. It will be instructive to examine the characteristics of some of these tasks, to see whether these characteristics distinguish them from the tasks that are more commonly computerized.

Transcribing spoken messages and reading handwriting requires a very flexible capacity for *pattern recognition.* Even human beings have difficulties with the spoken word, as any Yankee who travels to Alabama soon learns. The recognition cues that are used are subtle and flexible—as is essential to allow for the great inter-individual variations in speech. Several decades of research in the Bell Laboratories and elsewhere have failed to reveal completely the nature of the cues that human beings use, how they adapt these cues to variations in speech production, or how a mechanical device might simulate the human capacity for auditory pattern recognition. The same may be said about reading handwriting, or even reading hand-transmitted telegraphic code or printed documents.*

In fact, so refractory are these problems that they have generally been by-passed in attempts at automating message transmission. The dial telephone, by digitalizing the message and eliminating personal variability, makes it possible to control automatically a complex switching system. The mark-sensed card provides a (highly limited) means for a human being with a pencil to write a message that can be read by a machine.

Recent advances in technique have about brought us to the stage where machines can read and transcribe into more tractable form printed documents having reasonable variability in the shapes and sizes of the letters. The amount of difficulty that has been encountered in solving even this relatively simple problem underscores the intrinsic difficulties that are involved.

Let us turn to a slightly different kind of routine task which has only infrequently been mechanized: answering miscellaneous inquiries. The trick lies in the word "miscellaneous" and in the volume of information stored. There is not the slightest difficulty in storing on magnetic tape the population, land area, principal crops, and capital city of every country in the world and programing a computer to be able to respond to a question about them, such as: what is the capital of Argentina?

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* Bernard Gold, "Machine Recognition of Hand-Sent Morse Code," *IRE Transactions on Information Theory,* IT-5 (March, 1959), 17–24.

With very large bodies of information, however, it becomes uneconomical to search for information without the use of indexes and similar devices. The problem of designing appropriate storage systems, indexes and search procedures has given rise to the new subject of *information retrieval.* Reference libraries, insurance companies, abstracting services, accounting departments, the Patent Office, and other large-scale document keepers and document searchers all have information retrieval as a central task.

At first glance, the problems of pattern recognition and information retrieval do not appear to have much in common. In fact, however, the difficulties in both areas arise from the same fundamental cause: the tremendous variety in the stimuli that must be accepted by and handled by the processing system. The pattern recognizer that is to read the printed page must be prepared to read an "e" as an "e," whatever the size or design of the type and wherever it appears on the page. The file searcher must be able to find "that letter from Grumshaw," whether it be filed by the writer's name, his company's name, the subject, or whatever. A kind of flexibility is required that we associate with people rather than with machines.

Information retrieval requires some person or device to read and transcribe the information to be stored, some person or device to do the abstracting or indexing, some person or device to translate the questions asked of the system into terms that can be found in the index or abstracts. All these tasks are trivial enough if the set of possibilities is small and well organized, difficult enough if it is large and unorganized. In the latter case, the problems become quite like those of pattern recognition—or, even more generally, of problem solving. In fact, these tasks, even if they are often performed by clerks, do not really fit our definition of the clerical: examined in detail, they are neither routine nor repetitive—each task has to be rephrased and reformulated to bring it within the scope of the systematized part of the process.

The student of factory mechanization will recognize here difficulties in mechanization quite comparable to those he faces. Machining can be mechanized; but the pieces to be machined must be positioned, and this is a little more difficult to mechanize. It becomes particularly difficult if the pieces come in a variety of shapes and sizes. Highly mechanized processes can work in well-structured situations, but the structuring must be accomplished—someone must make order out of chaos.

Programed Problem Solving. Let us consider next some tasks that, at least at first blush, seem to require a higher order of problem solving than those we have called clerical. A company that manufactures and sells through retail outlets a wide variety of products must fix a price on each of the tens of thousands of items it carries in stock. A factory that makes two thousand different types and colors of paint must determine each week how much of each kind will be manufactured.

Each of the myriad decisions in such situations could be put as an exercise in Economics A. The problem is to determine the set of prices or the manufacturing schedule that will maximize profits. Unfortunately, the decisions are too numerous and too interrelated, and the data are too rough or incomplete, to make this approach feasible.

We turn instead either to "judgment" or to extremely simple rules of thumb. To set a price by judgment, we take into account the cost of manufacture and distribution, competitors' prices, our desire to offer the customer a full line of goods, our reputation in the trade, order backlogs, etc. We set a price that, "all things considered," looks reasonable. The procedure is extremely flexible because there is no factor that we cannot take into consideration if, in the instance in question, it happens to be important. ("This item has to be priced down, because a new style will come into the market next month.") It is the procedure of the craftsman, who handles each piece of wood according to its particular grain.

Rules of thumb seem almost the antithesis of judgment: We set the price by adding eighty per cent to the manufacturing cost as determined by the cost accounting system; we manufacture a new batch of item X when the stock on hand reaches a reorder point. But rules of thumb are not so different from judgment as they appear. First, someone must set the rule of thumb—and this is usually an act of judgment, judgment applied to a whole class of decisions. Second, we can always supplement the rule of thumb with a principle of exceptions—the exceptional case can be handled outside the system.

Finally, in those cases where the processes underlying judgment have been analyzed, these processes generally have turned out to be collections of rules of thumb, often with an implicit principle of exceptions superimposed. Even where no formal markup has been established, the price clerk has a "standard" markup in mind; where there is no reorder point, the stock clerk has notions of when stock is "too low."

The main distinction, then, between acts of judgment and formalized rules of thumb is that the former are in the mind and leave, perhaps, a little more room for flexibility to meet unusual circumstances than the latter. Especially in those situations where the number of decisions is large and where each one, taken individually, is not crucially important, judgment and rules of thumb come to much the same thing, and the difficulties of changing from an informal to a formal decision-making procedure are not formidable.

Formalization, in these cases, may actually increase the sophistication of the decision-making process, for it may prove economical to devote an amount of attention to the aggregate problem—designing the rules of thumb—that could not be justified in handling each individual decision. Thus, formal mathematical procedures for "optimal" control of inventories have been known, and even used to some extent, for a long time. More recently, with the advent of such operations research tools as linear programing, queuing theory, and dynamic programing, these formal procedures have reached new heights of refinement.

The newer techniques, resting on advanced mathematical tools and the power of modern computers to carry out the arithmetic, promise two kinds of advantages. First, they can handle large numbers of decisions more economically and at least as sensibly as these can be handled by cheap judgment (the only kind we can afford for them). Second, the interdependencies among individual decisions can be taken into account, and aggregated decisions made (e.g., the over-all factory operating rate, the aggregate inventory) that take into account the crucial variables that affect profit.

Formalization and mechanization of programed decision-making, particularly in the areas of scheduling, production control, and inventory control, are spreading rapidly (as a number of other papers in this book show concretely). There is every reason to suppose that in all situations where the volume of decisions justifies the change, the craftsman of such decision-making will be replaced by the clerical assembly-line worker.

The possibility of making the programs for well structured decisions explicit rather than implicit extends far beyond the tasks we have just described. There is now an important set of examples in the field of engineering design.* A customer sends in an order for an electric motor that does not quite fit a standard design, manufactured for stock. The order specifies certain performance characteristics of the motor—for example, its voltage, horsepower rating, operating temperature, efficiency, and so on.

Until the past two or three years, designing such a motor was usually the task of a professionally trained engineer. On receipt of the specifications, the engineer went to a file where were stored the designs of a large number of motors that had been manufactured in the past. He selected a design similar to that required by the customer and proceeded to modify it, using rules of thumb as well as engineering theory to suggest the appropriate modifications, and making numerous calculations with the aid of large tables of empirical and theoretical performance data stored in a shelf of large books. The finished design took the form of a set of manufacturing specifications that were then sent to the factory floor.

This work is not considered by engineers to be very creative—but it is regarded as engineering work, requiring judgment and experience. It is genuine work of synthesis, for the design cannot be "deduced" from the customer's requirements, but must be discovered. Two experienced designers may produce somewhat different designs from the same requirements, and the engineer thinks in terms of "good" design rather than of the "best" design.

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* G. L. Goodwin, "Digital Computers Tap Out Designs for Large Motors, Fast," *Power*, April, 1958.

Today, in several electrical manufacturing companies, this entire design job is performed by computers. The customer's requirements are fed into the computer; it searches through tape memory to find a similar design; it uses rules of thumb to modify the design, making calculations based on engineering data that are also stored on tape; it prepares the manufacturing specifications in the same form that the engineer prepared them. The procedure, like the one it replaced, aims at a good design—although at some points in the synthesis, particular design parameters may be suboptimized. By general report, the designs turned out by computers are at least as satisfactory as those previously prepared by trained engineers.

Where did the rules of thumb come from? These computer programs were written largely on the basis of the introspections of the engineers into their own design processes. "Judgment" was translated into rules of thumb and rules of thumb into computer routines. To a very large extent, these computer programs are simulations of the thinking processes of the human beings they replace.

When analyzed in this way, these design tasks turned out to be not very different from many of the "routine" clerical tasks that had earlier been mechanized. A computer program for motor design does not look very different in its structure from a program for computing payroll. The former program may be somewhat larger, it may have more conditional transfers, and it contains rules of thumb instead of formal regulations. Its most distinctive quality is that it does not proceed directly to its result, but involves a certain amount of trial-and-error search. It is this search activity, based on the rules of thumb, that gives it its capabilities of synthesis.

The motor design program is a prototype of an important class of problem-solving procedures that we shall call *heuristic programs.*[*] Their ability to solve problems by search and synthesis is based on a particular way of using the conditional transfer operation. In the payroll task, the program prescribes things like: Does the employee belong to Blue Cross? If so, deduct X dollars. These prescriptions take the general form: Classify, then proceed accordingly. In the design task, the program prescribes: Try A. Evaluate the outcome. If it is satisfactory, proceed to C, if not, try B. Here the general form is: Search, evaluate (classify), then proceed accordingly.

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[*] Speaking strictly, if the program is guaranteed to lead ultimately to the problem solution, it is called *algorithmic;* if not, it is called *heuristic.* The importance of heuristics lies in the facts that they often lead us quickly to solutions which we could only reach much more expensively by algorithms, and that for most classes of problems that human beings solve every day we possess good heuristics but no algorithms.

Nonprogramed Problem Solving. No one, to our knowledge, has estimated what proportion of all white-collar activity in business organizations is clerical, and what proportion involves programed problem solving as we have defined these terms. As a very rough generalization, the programed, the routine, and the repetitive bulk large in most jobs at the lower levels of administrative hierarchies; the nonprogramed, the problematic, and the novel take on increased importance at the higher levels.

But such a pairing of types of tasks with administrative level is only the roughest approximation. We have already seen that a good many things that clerks do involve pattern recognition or problem solving of kinds that are difficult to mechanize; on the other hand, some of the professional activities of engineers, and many of the decisions of the factory scheduler and even the factory manager, are reducible to computer programs. Whether we are concerned with technical feasibility or economic efficiency, we must ask what computers can do at each level of the organization, and we must expect to find at each level some things that are difficult to program, and some that are easy.

Let us consider two tasks that are usually regarded as characteristic of the higher levels of organization. The first is perceiving and foreseeing major changes in the environment, and bringing about basic changes in the organization's activities to adapt it to the new environment. The second is developing, evaluating, and selecting men to occupy the important positions in the organization (where they perform similar tasks at the lower echelons).

In both kinds of tasks the elements of pattern recognition and problem solving bulk large. External events do not come to the organization with their interpretations attached; and potential executives do not come to it labelled with their ingredients. Assessing large events and assessing people are pattern-recognizing tasks *par excellence.* Taking these events and these people as his materials, the executive creates plans of activity and designs plans of organization to attain his goals.

The prospect for computers' performing such executive tasks rests on our ability to extend their general pattern-recognizing and problem-solving capacities. Nothing we know about these tasks suggests that the basic processes are different from those involved in other forms of complex reasoning activity. Nor does our present knowledge of human problem solving—even of fairly complicated kinds—indicate that these basic processes are particularly abstruse. For example, one common problem-solving method of very general application is *means-ends analysis.* What does it consist of, applied to the present case?

We start, let us say, with a general goal: setting up a company to exploit a new product. We ask: what do we need in order to do this? We must manufacture the product and we must sell it. What do we need to manufacture it? We need a design for the product; we must determine what manufacturing steps, what materials, what facilities and equipment, and what kinds of labor are required. And so we continue to elaborate each task into sub-tasks, until we have an array of tasks that we know how to execute. At this point, we have an initial plan which we can evaluate by applying various side conditions to it: how much will the product cost if made in this way? at what price can we sell it? and so on.

This is a design process whose basic structure is very simple. We have *goals,* and associated with these goals are *methods* for attaining them. The methods, in turn, can be viewed as sub-goals that have methods associated with them. At some point in the analysis we stop because we have reduced the problem to a set of methods (which we may call operators) that we can execute with known (or estimable) costs. In carrying out means-ends analysis, the problem solver has some of the connections between goals and their associated methods stored away in memory—these associations constitute his "know-how." He also has techniques for acquiring those he does not already have: consulting specialists, going to reference books and trade literature, performing laboratory experiments, observing the practices of other companies.

Viewed in this way, problem solving by means-ends analysis involves information storage and retrieval combined with a relative, simple executive program for building up the plan by successive steps—each one like the others.

We have, of course, oversimplified the process in our description. Nevertheless, at least one computer program is now in existence, having little more machinery than we have just described, that is capable of carrying out means-ends analysis over a range of subject matters.* Provided with information about the basic rules of symbolic logic, it can discover proofs for theorems in logic; provided with the rules of algebra and trigonometry, it can solve trigonometric identities. It can do formal integration and differentiation, and there is reason to believe that, with some modification and extension, it will be able to reason about positions on a chess board. All of these tasks are better structured than those encountered in the everyday practice of business management, but they are difficult intellectual tasks, and the effectiveness of the program shows that a problem-solving heuristic of rather modest size and great generality is capable of coping with them.

Learning Processes. An effective program for means-ends analysis is probably one of the main tools of a good problem solver, whatever the area of human knowledge to which he applies his skills. A good problem solver is probably also usually a good pattern recognizer, but we know much less about the role of pattern recognition in problem solving than we do about such processes as means-ends analysis.

A man may have a very high general intelligence without being a good problem solver in a particular subject matter area. A great biologist may be unable to solve simple problems in mathematics or in economics if he has not studied these subjects, and a highly intelligent business executive may be a poor chess player. Effectiveness in problem solving in a given area depends on knowledge of facts in that area and of special problem-solving techniques that are applicable to it. And these skills, in turn, depend upon exposure to the area and upon ability to learn.

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* A. Newell, J. C. Shaw, and H. A. Simon, "Report on a General Problem-Solving Program," *Proceedings of the International Conference on Information Processing,* Paris, 1959. Forthcoming.

We should not, therefore, expect a computer possessing a good program for means-ends analysis to be able to make business decisions unless it has learned something about business. How can a computer learn?

Simple memorization is one part of learning. Anything that can simply be memorized can be learned more easily, and remembered better, by a computer than by a man. One important difference between an experienced businessman and an intelligent person who is not a businessman is that the former knows a great deal about business in general, and about his industry and his company in particular, which the latter does not know. But a computer can match this kind of simple knowledge, if it is provided with the facts to be learned.

The most important kinds of learning go beyond simple memorization. A man learns (or can learn) by experience—i.e., by what he has seen and heard and what he has done. This is so obvious that we take for granted that we learn physics by doing problems and performing experiments in the laboratory—not to create new knowledge about physical phenomena, but simply to comprehend and be able to apply what is already known.

In considerable part, learning from experience is a pattern-recognition process. We did certain things in the laboratory and got a white precipitate in our test tube. We ran an advertising campaign and sent some salesmen on the road and made certain product changes, with the result that we sold X dollars worth of goods. We learn from such complex experiences only by scanning the antecedent conditions for the patterns that produced the outcome—by ferreting out the cause-effect patterns. The usual steps of induction are required: forming hypotheses (possibly relevant patterns) and testing them. But nothing really new seems to be involved here: this is a pattern-recognizing and problem-solving technique applied to the problem of learning.

The conclusion should not surprise us, for it is a commonplace that good problem solvers are also generally good learners when they are exposed to a new subject matter. The implication we can draw for our present discussion is that, as we learn to increase the capacity of computers for nonprogramed problem solving, we will simultaneously increase their capacity for learning.

Here is the practical reply to the argument stated earlier, that a computer can do only what it has been programed to do. If a computer can be programed to solve problems, it can also be programed to learn to solve problems—i.e., to modify its problem-solving techniques in application to particular subject matter areas. Presumably it will do this in the same way that human beings do: it will be exposed to a variety of situations, will tackle them with its (inefficient) general pattern-recognizing and problem-solving programs, and will analyze its experiences to devise special-purpose methods for particular subject matter and to acquire the facts it needs to deal with that subject matter.

Again, we are not spinning out pure fancies. A number of computer programs have been written that allow computers to learn from experience. For example, the program that solves problems by means-ends analysis has the capacities also to remember theorems it has proved, to remember how it proved them (both of these are matters of "pure" memorization), and to remember that certain special methods have been effective in certain contexts. The last-named capacity begins to approach the kind of learning a good student does when he solves problems. A computer with this capacity can gradually, from its experience, acquire a problem-solving program far more powerful than the one initially programed into it—and more powerful, indeed, than the one its programer possesses.

In order for a computer to turn its problem-solving capacities effectively to the task of learning, it may have to be exposed to the same range and quantity of experiences and problems to which a man would have to expose himself in order to acquire the same learning. The computer's "photographic" memory would give it no advantage over the man. In both cases, the result of the learning would be a more effective special-purpose problem-solving program, lodged in the memory of the computer or the brain of the man, as the case might be. But at this point a very great advantage would arise for computers over men. A computer program, once evolved, can be transferred, almost effortlessly, to any other computer of adequate size by a simple process of memorization; while the man's program can be transferred to other men only through a process of education.

The invention of printing—the cheap multiplication of the written word—caused a revolution in human information processing. The potentiality created by computers for the cheap multiplication of problem-solving capacities is likely to be at least as great a cause of revolution. This potentiality will in all probability be a major factor in the computer's impact on the future world.

WHAT IS THE PRESENT STATE OF THE ART?

In our confrontation of management tasks with computer capabilities, we have not drawn a very clear line between present actualities and future possibilities. It may be helpful, by way of summary, to state where matters stand as of the beginning of the year 1959.

1) The mechanization of the kinds of repetitive clerical and computational tasks that are performed, for example, in accounting departments and in scientific research and design has already proceeded very far. Feasibility is no longer at issue—the problem is to find ways of doing it economically. The issues are almost identical with those of factory mechanization: mechanization becomes economical when the volume of tasks grows large and when they can be sufficiently standardized.

2) Mechanization, in combination with the application of sophisticated mathematical analysis, is being extended rapidly to areas like inventory and production control, where the decisions concern relatively tangible, quantitative matters. In these areas, the motive for mechanization is to secure better decisions as well as cheaper decisions.

3) There now exist several successful examples of the mechanization of professional skills—notably in engineering design. The initial motivation was mostly economy, but the mechanized procedures give promise of improving quality also.

4) Heuristic programs have been developed to the point where computers can be given the capacity to solve reasonably difficult (e.g., at the level of a college sophomore) problems requiring

genuine discovery and synthesis. These developments have not yet reached the stage of application to industrial problems.

5) Pattern recognition, a crucial process in handling poorly structured problems and an essential element in flexible perception of a "raw" external environment, is at present a major bottleneck in mechanization. It appears as a particularly serious difficulty in information retrieval systems, where pattern recognition generally turns out to be the most expensive part of the entire process. Pattern recognition is an active arena of fundamental and applied research, but it is exceedingly difficult at this moment to assess what developments are most promising and what the timetable is likely to be.

6) Programs to give computers the capacity to learn are also in an early stage of development. Enough progress has been made, however, to suggest that the learning capacities of computers will proceed apace with their capacities to recognize patterns and solve problems. The cheap reproducibility of computer programs will, over time, make it far simpler to transfer new knowledge and skills to computers than to men. In the long run, this capacity will prove crucial to the economy of mechanization.

Will computers do the work of managers? Our summary of developments indicates that the question of feasibility is rapidly being transformed into the question of efficiency. To see at all clearly the economic and social consequences that may follow would require a clearer crystal ball than we possess.

Since economic considerations will limit the transfer of tasks from human beings to machines, the shift, as it takes place, will be gradual. In this country alone, our present capital in human brains must amount, in its productive capacity, to several trillions of dollars. To duplicate this capacity in computers would presumably require an investment of comparable magnitude.

All of us have the same stake in the outcome. If the computer revolution occurs, the future will judge us, not by the balance sheets of our companies, but by our wisdom in securing the benefits of the revolution for the human species. Economic limits will provide us time to guide the development in an orderly fashion. It is not too early to begin to form plans.

SUPPLEMENTARY COMMENTS

By

Herbert A. Simon

WHENEVER WE TRY TO FORECAST the future course of events—economic, social, or technical—we inevitably have to do so on the basis of things which have happened in the past and with which we are familiar. We forecast by analogy.

In considering the impact of information technology upon the business firm, it has been suggested that we use the analogy of Scientific Management, considering information technology as simply Scientific Management all over again at a somewhat different level. Others have suggested, and I think I tend to agree with them, that information technology is really factory automation all over again. In seeking a proper analogy, we have to ask ourselves to define the characteristic of this thing we call "information technology." It may turn out that it is really composed of several things, all of which are related to each other by being related to the computer and to things like operations research. On the whole, the analogy that appeals to me is thinking of it as the automation of mental work.

It also makes a great deal of difference, in forecasting changes and their consequences, to remember constantly what point of view we are taking or what role we are playing when we are discussing these changes. We can consider the consequences of the changes brought about by information technology from the viewpoint of the manager responsible for the effectiveness of the business organization, or we can appropriately look at them from the point of view of the citizen concerned about information technology's effect on human values generally.

McGregor, in his analysis of organizations, indicates that he is not concerned about the happiness of people per se, but about the matter of effectively motivating them, which in turn is related to such concepts as happiness. I, as a citizen, am worried about the happiness of people. I am concerned about the effect on individuals' welfare and happiness of the changes we are discussing. But, at the same time, I recognize that our society relies mainly on the business enterprise to provide its goods and services, that the man who manages an enterprise must have as his primary goals the survival and profitability of his firm, and that he is not primarily concerned with dispensing happiness to people. When we look at this development as managers, then McGregor's view is not only a reasonable one, but the only one possible.

For us, *as managers,* it is futile to become involved in discussion of the goodness or badness of using computers. If they do a better job, then we will use them. If they are profitable we will use them; and if we experience twinges of conscience in so doing, then we will say, "We didn't really want to do this, but we had to do it because our competitors did." We will use computers for profit, or for economic survival. This does not mean, of course, that we are not interested in the effect of computers on employees. We are very much concerned, as managers, about their effects upon motivation and attitudes.

However, while those who have been doing pioneering work with computers in the management scene (such as the industrial participants in the Seminar) necessarily will appraise computers in terms of their effect on the business firm, they also have a right and a responsibility, because of their advantage in early insight and information, to assess and appraise the impact of information technology upon human welfare. An early consideration of the problem affecting human happiness and welfare may put us in a better position as citizens later to view these problems when they develop.

I would like to mention again two issues Allen Newell and I raised in our paper. One is the matter of technological unemployment. I simply do not believe this to be a matter about which we need be seriously concerned. We have dealt rather well with revolutionary sorts of changes in technology in our previous history. We have learned enough about economic policy to enable us to cope fairly effectively with employment problems.

The other issue is that of technological feasibility versus economic efficiency. It may well be feasible to teach a computer to play chess better than any human being, but at a price of $350 an hour while it is playing. No chess player in the world makes this much. Consequently, we will probably go on using people to play chess even though the machine might be able to do it better. This is just a special application of the economic principle of comparative advantage. This principle shows that the total social product is increased by the division of labor, even though one person or one productive agent might be able to do everything better than any other agent. In the case of computers versus people, this principle would indicate that, even assuming computers someday could do any task better than human beings, we would be likely to use them only on those tasks in which they had the greatest advantage relative to human beings. The rate at which we would substitute computer services for those of human beings at any given time would depend upon the relative prices of those services, which would be related, in turn, to supply and demand factors. The economics of the situation is well summarized in the remark of the airline pilot who, when asked if he worried over being replaced by an electronic guidance system, replied, "No. Where can you get a non-linear servo-mechanism which reproduces itself for $1000 a month?"

So much for the important issue of economic feasibility versus technical feasibility. Let us turn then to consideration of what computers can do today versus what they will obviously be able to do within a period of five years. We can start our analysis of present capabilities versus future potential by looking at the kinds of tasks that computers can do today versus the ones they should be able to achieve soon.

First, let us look at clerical tasks. Here we should distinguish between those which involve essentially copying and those involving the activities of information retrieval and pattern recognition. We are, in fact, today doing the copying operations on computers in a large number of installations. But a big bottleneck today in further application of information technology consists of problems of information retrieval and, particularly, of pattern recognition. The problem is to convert information into a form that can be used by a computer. This, in general, is the problem of taking the outputs of human beings, usually in oral and written form, and converting them into a form usable in computer systems. This particular pattern-recognition task turns out to be one of the most useful things that human beings can presently do at the clerical level.

Much of this conversion effort is really unnecessary at the present time. A good example is furnished by books. At present, men sit at linotype machines setting type used to print pages which are then bound into books. These books are sold in stores to various buyers, including libraries. Now, suppose one faces the problem of getting some information back out of some recently written article or book which may be in the library. This is an impossible task for computers, if they are expected actually to search library shelves. The task is almost impossible, or at least very difficult and expensive, even if we have already taken the quite costly step of reproducing the book on microfilm. In a few years we will undoubtedly be doing the obvious thing—putting the book on magnetic tape simultaneously with printing. This will immensely help the information retrieval problem and completely by-pass the conversion problem.

In general, a great deal of our present problems of converting information into forms suitable for computers arises from the fact that we worried so much originally about converting information into forms suitable for human beings. If human beings had never got into the act at all, we would not have these problems.

Now, if we move away from the clerical area up to the middle- and upper-level management tasks, the sky is the limit. We are already finding a variety of ways to get computers to do the kinds of things that we had previously thought could be done only by intelligent people using their reasoning and thinking capacities. A number of examples are presented in other papers in this book illustrating the application of computers to tasks of considerable complexity. At a research level today, as contrasted with an application level, we can find even more startling examples. We have computers which are performing certain kinds of problem-solving tasks in the area of mathematics sufficiently well to earn them passing grades at the college sophomore level. More important, these computers learn to do these things better in successive tries and learn not only to do specific tasks but to engage in general problem-solving behavior.

So, in searching for the limits on technical feasibility we have to ask, "Are there any kinds of things that middle- and top-level managers do which do not fall into the categories of computer behavior we have just mentioned?" In other words, is it any longer a question of technical feasibility or is it a question of whether it is economic to use computers to do the kinds of things that managers do? The technical problems do not look insuperable, though we must make the assumption that some major advances will be made in the automatic programing area within the next five to ten years.

On the economic feasibility issue, one important point must be made. Once one computer becomes capable of doing complicated high-level problem-solving tasks, it becomes immediately possible to have a number of others do the same. We have, in other words, a method for the cheap reproduction of brains. The implications of this are quite comparable, I think, to the effects of the development of printing on the cheap reproduction of books. Once we have succeeded in getting a program for intelligent thinking inside a computer, we can reproduce the program without the arduous and uncertain twenty-year training which is necessary in the case of human beings. If we are able to evolve this new and superior beast, its superiority will be right in its "genes," and it can reproduce itself. It will not have to teach its progeny. This suggests to me the possibility that perhaps the area of ultimate greatest comparative advantage for the computer is the area of creative thinking, in which it is extremely difficult for one person to tell another how he thinks. The computer may turn out to be more competitive, economically, with scientists than with executives; and more competitive with executives than with clerks.

MAN-MACHINE-COMPUTER SYSTEMS

By
*Alex Orden**

INTRODUCTION

Digital computers are already in fairly wide use in business. Some of their applications, as in the case studies presented at this Seminar, are of broad enough scope to raise important questions about the ultimate general effects of such developments on management. Although broad generalizations suggesting the great impact of computers on management are still rather speculative, we are advanced enough in these developments to start a careful examination of the concepts which are emerging, and thereby to base evaluation of the significance of current developments on an increasingly firm foundation. This paper will be devoted to such an examination and evaluation.

As general background, we can consider the capabilities of digital computers under three main headings: (1) their initial and extremely successful uses in scientific and engineering computation; (2) their use in business systems; and (3) the potential development of computer programs or new computers in which perception and logical processing of information are carried to a higher level than that which typifies the current uses of computers. We are dealing primarily with the second of these headings at this Seminar; but in doing so, we should be aware that in the long run, a broader perspective which encompasses all three headings will be needed for an over-all view of the impact of computers on management.

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Herbert Simon and Allen Newell's paper calls attention to current research on higher-level computer processes than are presently in practical use. Several terms have been used recently for such processes. I will use the term "artificial intelligence." Clearly there are possibilities, along the lines of research which Simon and Newell describe, of important developments for management. That area of research and the basic concepts involved are still in their very early stages. The status of such efforts and their relevance to the Seminar have been summarized in Simon and Newell's paper. My paper does not relate directly to that line of research; but in examining the current uses of computers in business, I find that the key role of computers might well be called "artificial intelligence"—*within well defined business systems*—and that this capability is becoming a vital ingredient for expanding the systematic aspects of business activity.

Progress along the lines expected by Simon may change the *relative* roles in perception and decision-making between men and computers in business operations, rather than the basic character of business management. It will not be surprising if research on computer methodology leads to increases in the "artificial intelligence" aspects of computer use; but it is very speculative to predict new computer capabilities which will be sufficiently basic and powerful to cause the development of a new basic outlook on business problems.

Turning briefly to the use of computers for scientific and engineering computation, the recent extensive development of mathematical models for solving business problems makes mathematical computation an important aspect of the impact of computers on management. The degree to which the use of mathematical models will be extended is, like the extension of "artificial intelligence," a matter of continuing research. The role of mathematical models, like the role of "artificial intelligence," is likely to become increasingly important as a segment of an over-all system, rather than as a separate activity.

Basic views about systematic aspects of management should be sought in the typical current developments of computer use in business, such as in the case studies presented at this Seminar. The two related areas, "mathematical models" and "artificial intelligence," will not be explored further here, for while these are important areas of development, central concepts about managerial systems should first be established.

The analysis which follows suggests that a great range of business systems should no longer be conceived as clerical systems or as man-machine systems, but as *man-machine-computer* systems. This phraseology is suggested as a way of expressing the expectation of what may be accomplished with computers. It is also, I believe, an appropriate point of departure for some immediate questions, such as: What is the current status of computer use? What are the prospects which we can extrapolate with confidence for its use in the future years? What are the implications for management of these relatively non-speculative appraisals? We should consider, for example, to what extent we are in a period in which the operation of business systems might be described as having men as dominant partners with computers as junior partners, and to what extent we are already seeing the control of a situation residing in a computer program.

SYSTEM CONCEPTS

The word "system" is used loosely in many situations. It is widely used by engineers to denote complex devices like guided missiles, communication networks, and computing machines. At the same time, the term is used to denote business operations of considerable scope for which rules can be prescribed. There is increasing evidence that mechanical systems and business systems should not be considered as unrelated subjects, but that we should rather seek a conceptual framework which covers all systems. In order to build a desirable conceptual framework, we must define the word "system" in an abstract way, while providing a definition which approaches technical precision rather than the loose connotations of everyday speech. For this purpose I propose this definition:

> A "system" is a complex entity whose predominant characteristics are the following:
>
> (a) Its functions have completely defined objectives which are determined outside of the system by those who design and program it. The desired responses of the system to varying inputs and environmental conditions should be considered a part of the definition of objectives.
>
> (b) It is composed of sub-units, which may in themselves be complex entities; but one need know only the external characteristics of the sub-units, rather than their internal structure, in order to link them into a system. I shall call the sub-units "components."
>
> (c) In actual operation the control of the system lies basically within itself. There are also external controls which can intervene and override the internal controls.
>
> (d) The controls and other aspects of linkage between components are programed. The term "programed" here is drawn from the digital computer field, but is intended to cover all types of specification of operating rules, guidance, scheduling, allocation, etc., for which the word "programing" is a satisfactory general term.
>
> (e) The programing is external to the operation of the system. It consists primarily of specification of rules, etc., under which the components of the system should function, rather than the actual specification and description of the functions. (The latter are in the domain of design and engineering rather than of programing.) Systems may be in varying degrees "pre-programed," that is, their programing is established once and for all when they are assembled, as opposed to being "operationally programable," that is, they permit programing by those who oversee the use of the system.

This definition is intended to encompass a very broad range: a guided missile, a digital computer, the scheduled operations of an airline, a manufacturing assembly line, the operations of an accounting department, etc. At the same time, the definition is intended to provide a basis for determining what entities should not be considered as systems. For example, a business organization as a whole, or any other organization which has some autonomy, cannot be said to have completely defined objectives which are determined outside of the organization, nor can such an organization be considered as being programed. Nor would we include a complex network, say, a network of roads, which is sometimes referred to as a "road system." The use of roads is programed only in a rather minor sense, although there are some rules which the users of the roads must follow.

Management clearly deals with systems in the above sense, in a clear-cut way at lower levels of management, and indirectly at higher levels. Lower-level systems may have to be viewed partly from the viewpoint that they are subsystems of larger systems, but that need not concern us now. The components of management systems are men, machines, and physical facilities. I will refer to these systems as man-machine systems, but will imply inclusion of other physical facilities as well as machines.

We seek a common conceptual framework for a very wide range of systems because we expect to find that those who design and those who manage systems which appear widely different have very important problems in common. In many ways, independent of the objectives and the components of a system, designers and managers of systems are concerned with problems of over-all reliability, with methods of information transfer, with methods of programing, and with approaches to system optimization. These concepts are general, rather than unique to certain classes of systems.

System reliability is an example of the general considerations which are important in all systems. Faults in one component of a system or in one segment of its information transfers can become faults of the system as a whole. The analysis of over-all system reliability involves statistical analysis, interrelated probabilities which are susceptible to mathematical analysis, and information theory. Malfunction of physical components, clerical error by human beings, machine errors in a digital computer, and even the results of poor choices at some point in a system, whether by a human being or as an outcome of a computer program, can all be dealt with, to some extent, as similar statistical and probabilistic issues of system design.

Programing deals with the interrelation of the components of a system to form a whole which can carry out the over-all objectives of the system. Although programing takes many forms, it always involves basically similar problems in areas such as the logic of describing rules of choice and action, the logic of information processing, and concepts of stability and control. It is clear that there are underlying aspects of programing which apply broadly to all systems.

Programing falls into three main categories: (1) aspects of stability, control, and logic which lie primarily within individual components of the system and often cannot be isolated from functional design considerations; (2) communication, stabilization, control, and logic which are involved in linkage and interaction of components without involving central control; and (3) programed central control components which provide unified communication and control over the whole system or major parts of it.

Before the development of electronic computers, activities and entities which would be called systems under the definition given earlier in this paper were largely limited to those which did not require central control components. Only human beings could provide central control, and their role was generally a mixed one in which one could not distinguish between the programing function and that of operating within a programed framework. With the advent of computers we have nonhuman central control components available. We are now seeing the development of programed computer control over entire refineries and missiles.

COMPUTERS IN MANAGEMENT SYSTEMS

In the case of management systems, central control now involves a combination of human beings and computers. Whether the computer appears to have a major role in providing a structure of rules for a business system, or a subsidiary one to human activities, its use is changing the basic outlook. Business activities of large scope are now truly becoming "systems" in which a clear distinction can be made between the programing of operations and the subsequent functioning of the system under the required set of rules.

Many business functions are being programed successfully, that is, being made into systems. On the other hand, at the present time there are many situations in which it is not clear whether the activities can be programed successfully or not. The introduction of digital computers has greatly stimulated efforts to program business activities; and it has become evident that computers are making it possible to establish broad systems in situations where, without computers, operations on a programed basis could not work. This role of computers is new, unique, and powerful; hence the name of this paper, "Man-Machine-Computer Systems."

Clearly, men are being required to work in a completely programed framework in an increasing number of business activities. Without appreciably relaxing the definition of a system as a completely programed entity, one can add the concept that some components or segments within a system may be allowed to program themselves, provided their programs fulfill specified requirements and are consistent with the programing of the system as a whole. To a lesser or greater degree, men in a system often have the option of being in part self-programed. My main impression of the paper by Simon and Newell is that they are presenting evidence of the possibility that in the future computers in a system may also be to some extent self-programed, as distinct from the more remote possibility that computers might even become programers rather than "programees."

The great advance which computers made possible in scientific and engineering computation, and the consequent important contribution to scientific progress, are based simply on the great speed with which computers can obtain solutions to mathematical problems. The scientific concepts themselves are not associated with computer programs. By analogy, much has been made of the importance of high-speed data processing to management. But in the use of computers in business systems, the systems themselves and concepts of business systems are affected by computers. The proper view seems to me to be that high-speed data handling is only an important collateral factor, whereas the basically significant development is that computers *extend the range of programability* in management.

A computer in itself may provide most of the components and control for a complete system activity. Most of these activities involve so-called "data processing systems." Computers are also being used as components of larger systems involving men and machines in business processes of large scope. In such cases, a computer may or may not be a "central control component" for an entire system —in fact, it is more likely to have a lesser role—but without the computer the entity as a whole could not be sufficiently regularized to form a "system." The computer may contribute to systematization in a variety of ways—as a high-speed information processor and transmitter, as a reducer of the "human factor" content of the situation, or as a control component for parts of the system. The significant thing is that, over and above such factors, the use of a computer makes it possible to view an entire complex business situation as a system.

In dealing with large-scope business activities which involve men, machines, and computers, it becomes difficult to establish definite boundaries within which the activities should be considered as a system. The human activities are often difficult to analyze and systematize; and often there are no sharp dividing lines between human control, which should be considered as programed and lying within the system, and decisions which are unprogramed and may be considered as overriding the system or reprograming it. Nevertheless, the procedures that have been established with the aid of computers in the companies which are represented at this Seminar go a long way toward major operations on the basis of a "system."

Several ways in which general concepts of systems may be considered as growing influences on managerial analysis are worth noting. These are intrinsic by-products of system developments but, in management, represent new outlooks: (1) It becomes necessary to consider the men operating within a system as programable in the same sense that machines, facilities, and computers are programable. (2) The use of flow charts is a rather basic scheme of representing systems. This has become well established in business data processing and production scheduling, but gains increased significance when applied to managerial activities of large scope. Managerial concepts in terms of *organization charts,* describing authority over functions, are replaced by flow chart concepts which describe the required relations between functions. (3) Since systems involve highly programable activities, managerial situations can be subjected to increasingly intensive analysis with the aid of mathematical and computational methods. (4) Specifically, along the lines of (3), analysis of managerial problems in areas which are systems can in principle be dealt with by simulation. Pioneering work along this line, which has been carried out by United Air Lines over the past several years, is being described at the Seminar by Warren Alberts.

THE PRESENT ROLE AND STATUS OF COMPUTERS

We are concerned here with trends and issues in the balance of effort in man-machine-computer systems. The subject is a large one—a full discussion could not avoid going into the relation of computers to partial or full production automation. However, the tenor of this Seminar is to minimize questions about machines other than computers. Therefore, the focus of the discussion here will be on the relative roles of men and computers. We might say that our topic is "administrative systems," in which physical aspects—production machines, materials, transportation—are the passive elements, while men and computers are the programed components which exercise control.

The discussion would be simpler if the high speed data processing function of computers could be distinguished clearly from their use as controls. There are cases involving relatively pure clerical automation where the high speed processing aspect is dominant. At the other extreme are cases in which computer programs are based on formal mathematical models, and with this accomplished, the work of the computer in managing a system is basic, while the high speed computation involved is necessary but of secondary interest. However, the case studies presented at the Seminar show the two aspects usually are inextricably combined.

There are several reasons for the interconnections: (1) Programed control over managerial systems is almost inevitably complex. Control generally cannot be expressed by clear mathematical models which involve a relatively small number of factors; instead it involves large amounts of information and extensive rules, which require interrelated data processing and decision-making. (2) Many activities which we conceive as straightforward clerical work turn out, during the course of programing for a computer, to involve much more intricacy of choice and judgment than had been anticipated. By the time such work has been put into a computer, one realizes that the function of the computer involves making many choices, as well as processing data. (3) The effort of the organizer of man-machine-computer systems is to put as much of the burden of straight data handling on the computer as possible. Regardless of whether the most consequential choices in the system are being made within a computer or by human beings, the computer is always involved in a great volume of data processing in direct association with its decision-making activities.

The popular term "office automation" suggests pure data processing. There are, of course, business functions which involve so much paper work—whether in banking or insurance, where the paper refers to money, or in manufacturing, where it refers to physical objects—that data handling itself becomes one of the important systems within a business. It is reasonable to speak of "man-paper" systems and "man-paper-computer" systems. These systems, which business tends to consider as clerical work, become complex, with many aspects of choice and some judgment.

There is a tendency to segregate "man-paper" functions into small enough system areas to be able, or at least to try, to go all the way to a "paper-computer" system (without men). By contrast, there is a tendency, in dealing with broader man-machine functions (remember that "machine" here means any physical object), to carve out a larger system and develop man-machine-computer systems.

The risk in the former case is that, without men in the system to handle some functions that computers—at least so far—cannot do efficiently, the scope of the system is unduly limited, and in fact the difficulties of interaction with other parts of the business may be increased. The functions that men can perform as a basis for establishing systems of wide scope are partly normal questions of programing, where computers to date are inefficient, and partly aspects where men can be allotted self-programing functions, which computers may or may not be able to do in the future.

The risk in the second case, where a broad man-machine system is converted to a man-machine-computer system, is that the system organizer may try to encompass too much. Generally speaking, however, those who have been dealing with this area of effort seem to be making more rapid progress toward successful outcomes than those who limit themselves to a relatively narrow paper work-automation approach. Even in the "paper work" area, those who take a broad view over a large segment of activity and head toward a man-paper-computer system need more time and money, but appear to be on better ground. Again, differences in attack on and types of problems encountered by those who concentrate on data handling and those who are concerned with business functions in a more general way require little or no distinction.

Thus the center of discussion at the present time should lie not in the conversion of man-machine or man-paper systems to "computerized" systems, but rather in the development of man-machine-computer systems and man-paper-computer systems.

It is worthwhile at this point to examine the relation of computers to their predecessors—bookkeeping machines, typewriters, cash registers, calculators, and punched-card machines. I will refer to all these tools, which preceded computers, together as accounting machines.

Fifty years of progress carried us a tremendous way in the machine processing of data before computers were developed. Punched-card machines brought data processing to a level parallel to that of automatic machine tools in manufacturing. The next step could have been automation in the sense of conveyor belts carrying objects automatically from machine to machine. There have, in fact, been developments along that line, except that instead of belts carrying cards from one machine to the next, the information is carried in electrical form on interconnecting cables. Such developments may or may not achieve an appreciable level of success. They involve problems similar to those of manufacturing automation, in that they trade flexibility for efficiency, and pay off only in very high volume operations.

Quite possibly pure data processing (which cannot be disregarded as an aspect of information technology) should still be considered linked primarily with accounting machines rather than with computers. Even "office automation," conceived as automatic handling of data in a purely clerical way, may still evolve from accounting machines. Computers can be and sometimes are treated as though one had a series of accounting machines with automatic conveyor belts connecting them; but there is no substantial evidence that this is the best way. In fact, at present, the best approach to pure clerical mechanization often involves use of accounting machines rather than computers, with some indications that this is an area where the conveyor belt approach is not generally desirable regardless of how it is done.

There is another approach to the pure data processing issue: The term "integrated data processing" has been used over the last few years in a specialized way. One might think that this term had arisen in connection with computers, but actually its definition among specialists refers specifically to accounting machines. It involves the notion that encoded media, such as punched tapes, should be produced on a machine by each person who handles data and that such media should carry information through an organization. For example, a salesperson's register would put out an encoded paper tape, this would go to a billing clerk and would be an input to that person's typewriter, which in turn would put out a tape with the original information plus added information, and so on. This "integrated data processing" is more applicable to facilitating data handling and communication in a broad managerial system than it is to the mechanization of large volumes of simple clerical work. However, the task of this kind of "integrated data processing" equipment is strictly that of processing data, using accounting machines, as compared to the very much broader functions of a computer. (The term "integrated data processing" seems an appropriate one here, since the focus is certainly on data processing; by contrast the widely used term "electronic data processing" seems to me a relatively poor one, since it does not encompass the essence of computer capabilities, which go far beyond data processing.)

The vital distinction in managerial systems between *data processsing* and *programing* (with data processing included) can be summarized by saying that, in general, the former should be mechanized with accounting machines and the latter with computers.

The accounting machine field is typified by a great variety of machines, each with very specialized capabilities. The computer field, by contrast, has the characteristic that the more the design of a computer is generalized, the better it is for almost every application. There have been many attempts to specialize the design of digital computers. Specialized machines have come from engineers with ideas to fit particular areas of application, from manufacturers with objectives of concentrating on a special part of the market, and from computer users feeling that their requirements could be uniquely specified and embodied in a computer especially efficient on their applications. Practically all such efforts have had little significance except that, as a result, many alternative ideas for computer design have been tried out, and that computers in a wide range of sizes, speeds, and prices have become available. One of the best indications of this situation is that there is little evidence that computers which have been produced for the business application market are any better for business applications than are the so-called scientific computers. Recently the trend has been toward combining the capabilities of these two general types of machines in machines which are for a general purpose and are best for both business and scientific applications.

Although current efforts to use computers in business often start out with a data processing point of view, the proper nature of computer application tends to emerge, and the efforts are gradually redirected to the broader goal of systematizing various business functions. Narrow initial points of view do, however, tend to persist to some extent and thus limit the effectiveness of system developments. The situation is in a state of flux, expressed in terms of hunting for and evaluating computer applications. One often hears about "successful" and "unsuccessful" applications.

The use of the terms "successful" and "unsuccessful" reflects a sense of novelty of work which is just being evaluated, but at the same time seems to reflect feelings of marginal discrimination. The applications called successful are in many cases felt to have made the grade by a narrow margin, and those that are called unsuccessful are felt to have come close but not to be quite satisfactory. In the many cases where there has been a relatively narrow, high speed data processing point of view, the marginal success or lack of success should be expected, quite apart from the newness of the venture, since the work can often be done as well or better on accounting machines. When the computer is advantageous in these applications, its margin of merit is often of little real consequence to the business.

In time, the connotations of the terms will change, or there will be new terms, to distinguish what appear to be necessary uses of computers from their optional uses. Computers will first become "necessary" simply because it will not be long before they have been embedded in organizations, and reverting to other methods, whether for pure data processing or for handling business functions as integrated systems, will become very difficult. More basically, however, we may find that man-machine-computer systems will handle some aspects of business in ways with which systems without computers, or businesses which have failed to program the proper functions, will find it difficult to compete.

Through much of the discussion so far in this paper, I have tried to extract generalizations which appear to be emerging from the characteristics of computers themselves and from experience over the past three years during which they have been coming into extensive managerial use. It seems to me that the answers to many questions are currently coming into focus, and that those who wish to do so can now extrapolate computer applications in business for, perhaps, as many as ten years. In brief, I think the pattern for the next few years has been well set by the past two or three years.

What makes this Seminar most intriguing is that we are nearing answers to questions which have longer-range significance but for which the evidence is so far not sufficient for extrapolation. Here are two key questions, which I do not think one can yet answer: (1) Let us take the premise that the programing of man-machine-computer systems is already penetrating into the middle-management area, and that computers should be viewed as more than a data processing tool in many systems. Computers provide an integrating link in such systems, and, as part of this function, make choices which determine some of the pathways of action. *The best relative roles for men and computers in these systems remains* *an unresolved question.* As questions in this area become resolved, we will be able to judge whether similar programings can penetrate to any appreciable extent into the area of upper management. (2) Will programed systems, covering major business functions (at least at the middle-management level) and relying on use of computers, gradually have a sufficient impact on business efficiency that, at least in some industries, companies which have incorporated such approaches will have marked competitive advantages over those which have not? We might even ask whether proper systems programing with the aid of computers will become necessary for business survival. The issue goes much beyond the implications of most current "successful" applications, which usually revolve around whether companies employing 20,000 to 100,000 people can save twenty-five or fifty people. The latter results need not be dismissed lightly, but certainly it is possible that graver issues are at stake. It is quite likely that some of the current computer application efforts are felt to be precautionary, in case really serious stakes are involved.

It is premature to do any more than speculate about such possibilities of far-reaching outcomes. Current efforts on new computer uses, on computer programing methodology, and on development of better computers are important issues, which will help determine the over-all outcome. A brief discussion of these efforts follows.

Computer Applications

The tremendous variety of efforts under way to utilize computers is evident. Earlier distinctions between data processing, primarily in business, and "scientific computation" for engineering and research, are being replaced to a considerable extent by a "systems" point of view toward most areas of application. The need to consider paper work from a broad systems point of view has already been discussed, and the conclusion offered that the broad implications of man-paper-computer systems can be as significant as those of man-machine-computer systems. The latter are typified in this Seminar by production, inventory, and purchasing systems.

It is becoming increasingly evident that many functions traditionally considered to be isolable as engineering are becoming integrated with other business functions. For example, in the petroleum industry current developments in refinery simulation combine engineering and economic considerations to a much greater degree than earlier approaches. Similarly, the use of computers in such areas as designing electric motors to meet customer specifications or estimating costs for bidding on bridge construction are systematizations of business functions, which differ from others primarily in regard to the segment within a business which is being isolated into a programable system. Even scientific work, as it evolves toward engineering, often acquires a similar character. For example, the extensive use of computers for designing nuclear reactors cannot yet be so closely integrated with business system developments as can the engineering aspects of refineries or bridges, but it may well be before long. The difficulties of converting some areas of engineering into programed form, and then linking these activities into a larger system which includes other business considerations, are similar to the problems of the use of computers in many areas of middle management.

Programing Methodology

Programing, in the sense of encoding computer routines, emerged and remains as a very substantial hurdle in the development of computers. It is a time consuming and intricate task. The problems involved are sometimes viewed as the major bottleneck to progress in computer use. The bottleneck is caused directly by the complexity of programing, and indirectly by problems of training needed programers and by the fact that expenditures on salaries of programers in many cases exceed the substantial costs of the computers themselves.

Because programing a computer is often intricate and time consuming even when the process being programed has been defined completely step-by-step, the issues of programing difficulty tend to be considered a special characteristic of computers, and possibly something that will become greatly simplified as the methodology progresses and as computer design advances. Actually, computer programing has a twofold character which underlies its difficulties: (1) The encoding of individual steps in a computer program is a simple matter. The difficulty arises because the computer itself is a system which is to be used as part of a larger system. The computer programer has to formulate sub-routines or other sub-programs which he can treat as additional components of the system, and link these components into an integrated system which is the over-all program for the computer. The planning of a major sub-program is somewhat akin to designing an accounting machine. Generally, the sub-programs and the over-all program must be designed to meet a variety of circumstances, and, in fact, if the programer makes his objectives too narrow, he finds that his program is soon scrapped. (2) The above applies even when programing for the solution of well defined problems, even relatively simple mathematical problems. When computers are applied to general programable systems in business and engineering the difficulty is compounded, since problems of programing the outside system are concurrent with the problems of programing the computer. The two aspects of system development become to a considerable extent inseparable. The whole range of problems involved is sometimes believed to be a bottleneck in computer programing, but is actually a larger issue which includes the problems of programing some system in which the computer will be used.

There are substantial efforts under way to simplify computer programing. These efforts have already become an inportant aspect of the computer field under the heading of "automatic programing." Initial efforts along this line were directed primarily toward simplifying the encoding of individual steps in computer programs. More recent efforts, which have been successful for some types of computer problems, are directed toward providing automatic generation (within the computer) of sub-units of a program and partially automatic linking of these sub-units.

Since a computer program is itself a "system," the aim of automatic programing is in part toward new and partially automatic methods of organizing systems. This is a concept which may become relevant to the programing of business function systems as well as for computers per se. Moreover, if methods emerge which go beyond present approaches to computer programing to a level appropriately called "self-programing" within the computer, they will probably emerge from automatic programing research. Present developments in automatic programing may be described in terms of the translation of symbols and symbol combinations into computer programs by automatic generation of sub-programs. This is not quite "self-programing" in the sense that systematization of decision-making by human beings is self-programing.

Computer Developments

The technology of computer design is still developing so rapidly that one cannot judge whether we know enough yet about the ultimate nature of these machines to estimate the scope of their impact on management. We cannot say, for example, whether or not reduction in computer size and perhaps in computer cost through transistorization will be of major significance. Nor do we know whether development of devices for automatic reading of printed characters will become economically feasible for relatively general use (as distinct from specialized efforts, such as those for handling bank check identification).

In addition to important developments in the elementary parts of computers (e.g., transistors, and major components such as input devices, large memories, and so on), there may still be major developments in the system organization of computers. At the moment the trends are interesting and relevant to this discussion but are probably not of major significance. System developments seem in general to be toward maximum flexibility so that a given computer is suitable for all types of application. The trends are these: (1) to permit a greater variety of peripheral devices to be attached optionally to a central computer; (2) to permit several computer components to function independently at the same time, but under the control of a master program (the most recent steps along this line are toward having several programs under way at the same time, one or more of which may involve human interrogation of the machine at any time without interrupting an ongoing basic program. A human-like capability to shift attention from one subject to another is involved); and (3) as noted earlier, to combine features desirable for large-scale data handling with those for very high speed mathematical calculation.

EFFECTS ON MANAGERS

The main objective of this paper has been to examine the potential effects of digital computers on managerial systems rather than on managers. The use of computers in basic applications to management problems can be distinguished from other recent developments which we are classing as "information technology." However, any significant examination of the effect on managers should turn for the most part to the effects of information technology as a whole.

Upper managements are quite actively involved in evaluation and plans for the introduction of computers—in fact, at the upper-management levels concern with computers currently overshadows other aspects of information technology. The issues involved are a variety of natural matters of management concern, such as: (1) the return vs. the substantial costs of the new facilities (which should be considered as matters of capital investment in computer programing as well as in computer hardware); (2) the merits of increasing the speed and scope of information they receive about company operations; and (3) the reliability of large integrated machines, in view of the difficulties in case of breakdown. Such matters are only indirectly associated with questions of over-all impact on organizations and on managers. Top managers are so far rather unconcerned with such possibilities as the likely effects on middle managers, the less likely possibility that even the top managers will be affected, and the possibility of significant effects on the broad aspects of centralization vs. decentralization.

When we turn to middle management, the situation is very different. Taking information technology as a whole, rather than just the introduction of computers, the fact if not the nature of its effects on middle managers is becoming highly evident. The situation is extremely complex and unpredictable. The degree to which the outcome will become general still depends on the ultimate breadth and merits which information technology will achieve. With regard to line management, one hypothesis is that the number of middle managers will remain relatively unchanged, but that their scope and status will decrease because of the increased programing of system functions. On the other hand, one can equally well hypothesize a decreased number of middle managers for whom the increased formal programing of the system is compensated by a greater span of control, so that the over-all requirements on them remain about the same as today.

Another possibility, which might be concurrent and part of development along either of the above lines, but which is more likely a distinct third avenue, is that of widespread professionalization of middle management. The possibility of such professionalization is foreshadowed by the recent growth of such specialists as computer programers, system analysts, industrial engineers, and others who have a staff role in relation to middle management that is akin to the traditional relations between line and staff in upper management. It is likely, however, that the line-staff type of relationship in top management is quite different from the proper relationship between middle managers and professional specialists. The distinctions in the middle-management area may blur almost to the vanishing point; that is, middle management may find it necessary to become quite highly professionalized with a resultant fluid interchange between line and staff positions. Extending the scope of programed business functions, co-ordinating programed functions, and applying analytical techniques in these activities will have to be joint activities of line and staff in the middle-management area.

Professionalization of middle management would have repercussions on top management, but perhaps none of great significance. The paths between top management and middle management would change, perhaps in ways which would facilitate upward and downward mobility. Top management is increasing its use of staff, and the increasingly professionalized middle managers should be able to move more easily than they do now into the top-management staff areas as well as into higher line positions.

It becomes tempting to suggest that the ultimate outcome will be professionalization at top-management levels, a movement which might be compared to that from the earlier owner-managers to today's salaried executives. This is, however, pure conjecture, whereas there is a good deal of evidence that professionalization of the middle-management area is fast approaching.

DISCUSSION AND SUMMARY

VOGT: One problem we face in industry is that the kind of thinking expressed in these two papers is extremely rare amongst those people whom we are trying to use in developing our own application of information technology.

GROSZ: We have felt this same lack severely. Our own training efforts have not done too well in making our people proficient in adapting computers to particular applications. Our feeling is that there should be something which we call "an application analyzer," a computer program which will tell us how to go about making a computer application if we tell the computer what we want. We would have to be able to tell the computer two things: characteristics of the system or application stated in very broad terms, and the capabilities of the machine which we would use. To develop such a program, it is necessary to develop a machine-independent language, something that the computer manufacturers have not succeeded in doing so far.

VOGT: We have evolved a program which does a great deal of our programing for us, but we still have a lot of manual intervention. The disturbing thing is that, from our reading of the literature, we seem to be ahead of most others in research on this problem. Since we are primarily a business concern and not a research organization, we are puzzled as to why the logical sources of research—the schools and the manufacturers of the equipment—seem to be lagging.

SIMON: You have pointed to a very important matter here. The speed with which this technology develops and spreads depends upon the amount of effort put into its development. So far, those companies which have been in the lead in using this technology have borne the bulk of the developmental costs. The gains from these efforts, though, will accrue to any future user. The best hope for rapid development, of course, is that the schools and the government and the manufacturers of equipment will perform their respective roles in development.

An example is in order. Perhaps the earliest application of linear programing was to a military problem in the late 1940's. The first conference on this subject was held at the University of Chicago in 1948. Probably the first specific industrial application was tried out in 1950 and 1951 by two people from the Carnegie Institute of Technology in co-operation with a major oil company. They dealt with the problem of blending aviation fuels. When the data were gathered and the basic technical work done, this particular oil company did not do the further developmental work necessary to make this a working tool. A few years later, however, Standard of New Jersey did pick up the job of development, and by 1956 they had a working program for blending fuels. Other companies can now get the results of this development virtually free and apply it to their own problems. Similarly, with problems such as we have discussed this morning in the area of automatic programing, the work will have to be done in the labs first and will be followed in some years by industrial application.

ALBERTS: I am reluctant to urge the research role upon the computer manufacturers. I believe that a great deal of harm was done by having the manufacturer's research people determine the first (and easiest to sell) application of computers. They had no real idea of the needs of business in a broad sense. It is up to the staff people in business to develop this concept of their needs and then seek out the manufacturers. It is up to the people in industry to do the kind of research necessary to an understanding of the basic processes of business and to pass this to the universities and the manufacturers as material around which they can do their developmental work.

RUSH: I wonder if other industrial participants have been concerned about the problem of maintaining the confidential character of the program they have developed.

VOGT: We have given considerable thought to this. We attach great competitive significance to the work we have done and, being naturally concerned about the corporate welfare of our company, are concerned about our program's remaining confidential.

SIMON: Putting on my hat as John Q. Citizen, I can see a difference between action that is good for a company and action that is good for society. I don't believe that at the societal level we can long tolerate individual companies' keeping major advances to themselves. This, in my mind, raises serious questions about the appropriateness of research at the company level, and even perhaps at the computer manufacturer level, although the manufacturer has more motivation to communicate the results of his research. The importance of fundamental research by universities and government organizations is clear-cut. We have dealt with similar problems before, as is illustrated in copyright laws and patent laws. The protection given the individual in these cases is very small, particularly in the case of patents, where nine times out of ten anyone who can see the patented device is able to take steps to produce something which does not violate this patent. In the case of computer programs, "the reproducibility of brains" is the major source of their efficiency from the viewpoint of society. In my judgment, society will not tolerate a restriction of transfer of information. This is particularly true with respect to the most general types of programs—general problem-solving and learning programs.

MCGREGOR: But aren't you talking about transmission of theory rather than transmission of particular programs?

SIMON: No. To illustrate, suppose we had developed a general problem-solving program, particularly with learning ability built into it, and we let it run and run solving different problems. One morning we wake up and find out that this thing is really a genius at problem solution, far exceeding anything individuals or organizations have been able to accomplish prior to this time. What we want is not a theory about this program and what lies behind it; what we want are copies of this program which can be put to work elsewhere continuing to learn and improve in a number of situations.

ALBERTS: One problem we may be overlooking in this discussion is the fact that merely because a program is available doesn't mean that it will be accepted by an organization. There are probably many organizations which, if they had possession of all the programs written to date in all companies, would not be able to use them for a long time. There is a problem of assimilation of new information.

SIMON: May I propose an analogue here? When I was a kid nobody in his right mind would take off in an automobile unless he understood the workings of all its mechanical parts. It was a source of pride and satisfaction to the Model T Ford owner that he could take care of any mischance short of a broken casting. Later, the manufacturers began to do things like taking the hand choke off a car. Many people said they wouldn't touch a car that prevented them from maintaining control of the richness of the mixture. Gradually other control devices were taken off the cars. It's got to the point where today very few car owners would dream of looking under the hood when trouble develops. They simply call the garage. As automobile drivers today we take a lot of things on faith. Years ago we demanded to know all about how these things worked as a condition of operating the automobile.

And so with the computer. Increasingly companies will take it and its programs on faith, giving up the demand to know exactly what happens, understanding it in broad outline and being able to adapt it to managerial uses.

ORDEN: It seems to me that a great deal of what we have been discussing so far has been equivalent to programing systems analysts. This is about on a par with programing the engineer's work on designing electric motors. This is an advance but not a very great advance, and I wonder if it isn't possible to go much farther. Specifically, I wonder why more companies are not thinking in terms of corporate laboratories such as the one set up in United Air Lines. Certainly corporate laboratories should be expected to grow in number just as industrial research laboratories have in the last twenty-five years.

GROSZ: It seems to me that if we can expect the development of programs with learning ability within the next five to ten years, and

I think we can, then we face the danger of a waiting period while we gather the understanding of information flows within the company which we can adapt to these programs. I think that in the absence of corporate laboratories our program development will proceed far beyond our understanding of internal information systems.

Alberts: We feel that we have already developed an understanding and conception of our internal systems which go beyond the capacities of present hardware. I think that the order of progress should be reversed—that the company must think through its problems carefully first. Often they turn out to be much simpler than would appear at first glance. By thinking out one's problems it is possible to save a great deal of programing effort.

I think little attention has been directed in today's discussion toward what is meant by learning and creating, although Simon mentioned this in his paper. Our own management has been somewhat oversold by claims about the potential of computers in these areas. I think we should be careful in making statements to laymen about these matters, or inordinate claims may retard development.

Grosz: Much the same thing has happened in our company in the operations research area. We haven't been careful enough to distinguish between what is operational and what is research, so that often our top management thinks things are operational which are still in the research stage and a great deal of disappointment results.

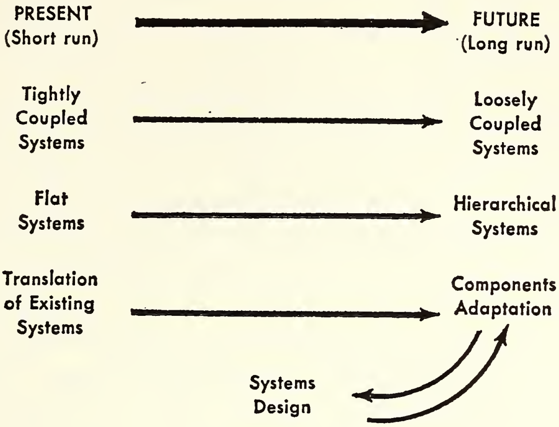
Simon: I agree with both these statements. We need to attach time labels to any discussion, so that people listening to it know what is near and what is far away. But I would like to stress the point that what I am talking about are things which I believe to be feasible in five to ten years rather than in ten to twenty years. We have programs on computers and running at the present moment which permit computers to "think" and to "learn," if you define these words in terms of the processes which we can observe in human beings when we say they are thinking and learning. It is a little more difficult to say what is creative, but we do have an example of a computer which has produced a proof in symbolic logic which is more elegant than the proof for the same theorem produced by Whitehead and Russell. If I had produced this proof I would have thought it creative.

(Professor Simon was asked at the beginning of the session on computers to make some notes during the discussion with the idea in mind of presenting at the end a brief summary of the state of the art and its future promise. His succinct and well organized summary provides a guide to the papers and discussion material in all of Part II.)

SIMON: I think it is clear from the written materials presented in the Seminar—ours as well as others—that all of us at the moment are really working on components of a technology. All of us here have been thrown into some particular problem or class of problems that involve information technology, and, like reasonable people, we have thought about the nature of the problem as we have worked with it. However, the point of view that each of us has, the impact that this technology has made on each of us, owes much to the particular phase of it which we have been working. For example, the reason Allen Newell and I seem to be the apostles of the long run is that the particular project we have been working on for the last two or more years has been a "wild blue yonder" project, and we haven't had to worry about such details as producing materials and shipping them out the door. The rest of you have been dealing with particular areas of decision problems in different companies, and have been looking at the component problems at that level.

Both Alex Orden and I, as well as some others in the Seminar, have proposed to the rest of you "maps" of the territory under discussion here. So I will begin my summary with a sort of map of maps. This problem of summarizing, you see, is really a problem of systems design. I'll try not to be too elaborate, but seek only to find a framework that will hold what both Alex Orden and I have been saying and maybe some of the other discussion as well.

Sticking to technology, and ignoring the social implications, I visualize a sort of map of transitions (see Figure 1). The time line runs from left to right on this map, with the left-hand side corresponding to the short run and the right-hand side to the long



Section II-2

PRESENT
(Short run)
FUTURE
(Long run)
Tightly
Coupled
Systems
Loosely
Coupled
Systems
Flat
Systems
Hierarchical
Systems
Translation
of Existing
Systems
Components
Adaptation
Systems
Design

Figure 1

run. Our present technical capabilities lie largely in designing systems which (to use Orden's terminology) we might call "tightly coupled" systems (computers doing paper work that was already on punched cards is an example)—systems where there are not a large number of choices involved; where, when we look at the computer program, it is largely a systematic program for chewing up some data and producing other data. One direction in which we are moving, illustrated by a number of the examples of application presented in this group, is toward much more loosely coupled systems. Such systems involve large measures of choice or, in computer terms, large numbers of conditional transfers. When you program the computer so that ninety-nine per cent of the time it is doing nothing but transferring to another cell, then you are beginning to get programs that can handle these larger aggregated systems; systems in which the output of one part is not just an automatic and inflexible input to another part, but leads to some problem-solving activities which then become input to the other parts. We are already approaching this, as is illustrated by some of the examples of the work the rest of you are doing. This transition is represented on the top line of my map.

Then, looking at the second line, we see a related distinction between "flat" systems where the components are sort of one-piece

—a payroll procedure, or the like—and hierarchical systems. And, again, we are moving from the first toward the second, from flat systems to systems of systems of systems. You can collapse these hierarchical systems when they are tightly coupled, but when they are loosely coupled their hierarchical character persists, because the person dealing with the over-all system really does not know very much about the details of the components. There lies the peculiar problem of systems engineering: How do you design a large system on the basis of only certain gross properties of the sub-systems? You can do this only if you have some techniques for handling loosely coupled systems. In a tightly coupled system you really have to understand the components in detail. Our programing problem today is a problem, in considerable part, because the thinking we do about larger systems—even if we treat a payroll as an example of a larger system—is strictly dependent upon the detail of what has been built into the computer at the machine instruction level. A large part of current programing research is concerned with finding ways of allowing people to work on components—allowing some people to worry about organizational design and other people to worry about machine design and still other people to worry about intermediate levels—and then fitting these pieces together without everybody's worrying about everything at once. Understanding how to create these hierarchical, loosely coupled systems is a matter of understanding how to do systems engineering, without at the same time having to do components engineering. We do not know very much about how to do this now.

Now dropping down to the third line on my map, we can ask ourselves: How have these distinctions influenced the kinds of activities to which computers have been applied? We started, you remember, with flat, tightly coupled systems that deal with today's problems. Our initial computer programs, therefore, are essentially translations. We take activities that are already pretty well systematized and say: Now let's consider one task at a time, and find out how to put these activities on a computer. Maybe payroll wasn't the right activity to start with, but that is debatable. If the problem was to find out what computers were like, then perhaps a familiar task like preparing payrolls was a pretty good thing to start with. In the process, people have learned something about computers, and they have not simultaneously had to learn about systems. We already know how to prepare payrolls.

Later on, when we understand the computer, we begin to think more about component adaptations. If we are going to do a task efficiently on a computer we find we need a different computer from the one with which we started. We may get to this stage of component adaptation very fast. For instance, a large part of the United Air Lines reservations problem turned out to be one of getting appropriate hardware. The systems aspect of it was rather simple.

Then, when we have some experience in component adaptation, we begin to fly free—we begin understanding systems design. In creating new systems that are not just translations of systems used under other technologies, we begin doing systems design. I think we are just entering this phase now. We were shoved temporarily off the track in using computers because we had to select some things that we already knew and learn how to do them on the computer. We are just beginning a period that is suggesting to us new ways of constructing systems and new ways of making decisions in organizations. This is, in turn, suggesting new requirements in computer design, and perhaps new requirements in organization design. The horseless carriage is turning into an automobile. It is the secondary loop we have set up here that is going to produce the major, unanticipated effects of this whole development.

From a technological standpoint it is crucial, if this buildup is to occur, that we learn how to handle complex hierarchical systems in such a way that we can deal with sub-systems without dealing with the whole; and that we learn how to deal with subsystems without having to deal simultaneously with all the other components—that we learn, in other words, some of the techniques of making flexible couplings among systems. This is our big problem of systems design today.

PART III

Organization: Concepts and Problems

"In the broad view it appears that the distinctions between line and staff are becoming blurred. Perhaps the most important reason is that the nature of management is changing, and the line is beginning to look like the staff."

INTRODUCTION: PERSPECTIVES ON ORGANIZATION AND THE MANAGER'S ROLE[*]

By
Douglas McGregor

IT IS IMPORTANT, I think, to recognize that there are a number of ways of viewing industrial organizations, each of which may be perfectly valid. The industrial organization might be viewed as a wealth-producing mechanism, a communications network, a set of power and status relationships, or an elaborate machine-man system, and perhaps in other ways. Although each of these views may be useful, it would be a mistake to assume that any one of them adequately represents the organization as a whole. The fable of the five blind men and the elephant is appropriate to this point.

In addition to the ways of viewing the organizations which I have just mentioned, there are a couple of other views that are useful in making some points I wish to bring out. First of all, the organization might be viewed as an economic instrument for serving individual needs. Second, it might be viewed as an economic instrument for serving the needs of society. These are important and vital needs in both cases.

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[*] This essay contains comments made by McGregor at the opening and near the end of the Seminar. The comments supplement the papers by McGregor and Bavelas and help to relate both of them to points made during the discussion of organization problems in the Seminar.

If we view the organization as a device for serving individual needs, it is important to recognize that these needs change through time, and that the organization must take cognizance of this fact. We must recognize, too, that individuals have ways of coercing or imposing restrictions upon the organization if it fails in some way to meet their personal needs. Well documented activities of the blue-collar worker in industrial organizations (restriction of output, sabotage, and so on) illustrate the point.

If we look at the industrial organization as an instrument for serving the needs of society, we must recognize that it is also possible for society to impose restrictions upon the organization, and that it frequently does so. Familiar examples are the wage and hour law, workmen's compensation laws, and anti-trust laws. Very often these restrictions are imposed because management has failed to recognize new trends in the needs of society and to adapt to them.

One way of looking at these restrictions, whether individual or societal, is to consider them as examples of stupid behavior. I think management tends to regard them this way. But an alternative way to consider them, and I think a valid way, is to see that these restrictions are often a result of inappropriate managerial behavior, and that it would be useful for the manager to think of them in these terms. One certainly does not call water stupid for failing to run uphill in a channel that one has dug for it, or regard the failure of kerosene to extinguish fire as stupid behavior on the part of the kerosene. When the manager, however, looks at individual behavior which he does not like, he is inclined to impute such behavior to stupidity on the part of the person rather than to inappropriate behavior on his own part.

A good example is the well-known worker interferences with production which resulted from early applications of Scientific Management. Early scientific managers insisted upon treating human beings as glorified machine tools. These managers emphasized standardization almost completely, and they eliminated consideration of those elements of the work situation which are important to people as individuals. As a result, the workers engaged in output restriction, rebellion, and sabotage. The application of Scientific Management was not just a matter of de-skilling a job, it was really a matter of de-humanizing it. The men responsible for this—the engineers—did not see things this way at all. Their interpretation of the workers' reaction to their techniques was that people were simply too stupid to see what was in their own best interest.

I believe that the assessment of the Scientific Management approach has been inadequate. The gains imputed to standardization, to assembly-line layout, and to complete planning of one man's work by another do not take into account the costs—the very high, yet hard to measure, costs—that result. The reaction has really been quite costly. The militant unionism of the 1930's must certainly be charged in large part to the long repressed feelings of hostility generated in the work force by the techniques of Scientific Management. Actually, many companies have abandoned the incentive schemes that came out of Scientific Management after they had an opportunity to make a full-scale analysis of the various costs associated with them.

The work done by the Tavistock Institute of Human Relations in England has shown that in some instances the results imputed to the application of Scientific Management techniques can be achieved by an approach which is directly opposite to it. An American example illustrating this same point is the successful application in many industrial situations of the Scanlon Plan. In both cases the emphasis, in contrast with Scientific Management, is upon retaining judgmental elements in the individual's job, on the importance of the group as a natural working unit in contrast with the individual, and upon the reliance upon internal control in the group rather than upon external control.

I think the Scientific Management developments are quite analogous to the new information technology. All we are talking about now, in a sense, is moving the philosophy of Scientific Management up into higher levels of the organization. The information technologist may bring about reductions in manpower and improvements in productivity. He also expects to reduce human error, and to leave less room for human ingenuity, to bring about more standardization in the organization, to make more people into passive agents of higher-level decisions (in other words more centralization), and to give staff groups a more central position in the organization.

I want to raise the question of society's reaction to all of this. What will be the internal cost to the organization using information technology? What will be the cost to society, and to industry, of reducing the role of people in the exercise of judgment and ingenuity? The answers to these questions will be very important to the managers and should have a considerable effect on how we perceive the installation of these developments and their subsequent use.

THE COMPLEXITY OF ORGANIZATIONAL ROLES

Although I have no clear picture in my mind concerning what we have learned in this Seminar about changes in the organization as a result of information technology, a few things have become obvious to me that were not apparent before we got together.

The first is that the language of organization which we have been using for years has become obsolete. In particular, the term *staff* no longer has any precise content. It is not very useful in discussing the kinds of changes which we see coming into organization. At the same time, however, we have no new vocabulary that we can substitute for the one which has become rather useless. It seems to me that we are going to have quite a difficult time discussing the new organizational relationships which may follow the application of information technology when we use a vocabulary which does not pertain to it in any realistic way. The original use of the word *staff* grew out of what was called the military form of organization, and involved the concept of unity of command. In a modern business corporation, there is no unity of command above the level of the worker. Many people influence the individual in the decisions he makes.

The second thing which strikes me is the problem we have in using the organization chart. We have been in the habit of drawing such charts with little boxes on them as though there were tight boundaries around each job. The Seminar has brought out the fact that the functions of individuals are all interrelated, and that all information flows among these positions freely.

A third point is that each manager plays a variety of roles. The man we call the line manager sometimes behaves as a line manager —that is, he issues commands and gives orders. But sometimes he functions as a staff man in an advisory relationship to his boss, sometimes he functions as a counselor to his subordinates, and sometimes as an adviser to his colleagues. Occasionally, he investigates matters strictly on his own. Each of these functions calls for different behavior on his part, but we persist in talking about him as though he were behaving in some simple fashion. This is illustrated most clearly when we discuss the role of the information technologist. Sometimes he is advising top management, sometimes he is laying out plans and devising systems, but sometimes he is setting up rules that other people have to follow.

A couple of years ago several of our degree candidates did a little piece of research which I think applies to this area we are discussing. These men set out to study some of the sources of conflict between staff and line in some big companies. They singled out two functions: accounting and personnel. They went out and talked to all levels of the organization in every case. They talked to the top people about how things had been set up, and they talked to the bottom people about how things actually worked out. They found two things. With one exception, they found no correlation whatever between the degree of adherence to traditional staff and line concepts and the amount of conflict that existed among managers. The one exception was the company in which there were no apparent distinctions of any kind. Everyone behaved like staff. The conclusion they reached was that what they had found in this organization was not unity of command, but unity of purpose. In this company, managers had succeeded in getting some objectives to which all were committed and which all understood. They were able to share each other's problems, and it made no difference who was line or who was staff.

One of the things I see developing from the application of information technology is a great deal more ability to get and communicate common purposes. The purpose may be to produce a certain number of gadgets within the next week, or it may be something else. Nevertheless, this new technology makes it possible to share common goals among many people—goals that are known, and known in detail. These purposes can be put into quantitative terms, and understood by everyone.

THE ROLE OF STAFF IN MODERN INDUSTRY

By

Douglas McGregor[*]

THE OBJECTIVE IN ESTABLISHING any staff function is to provide help to the organization in the form of specialized knowledge, skills, or services. Achievement of the objective depends upon how well three requirements are met: (1) appropriate help must be available to the organization; (2) it must be utilized; and (3) it must be equitably rewarded.

DIFFICULTIES IN ACHIEVING STAFF OBJECTIVES

There are many indications that none of these requirements is very well fulfilled in U.S. industry today. In the first place, help provided to one organizational level is often perceived by other levels as interference, as a burden. Middle and lower levels regularly make this accusation with respect to almost any staff group which reports higher up. They perceive the staff people to be narrowly concerned with their own specialty, long-haired, impractical, indifferent to line concerns.

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Second, there is widespread, even if not well documented, resistance to staff activities and effective sabotage of staff objectives. Evidence such as Argyris* reports with respect to accounting department budget controls could be duplicated for virtually any staff function. The situation in middle and lower management is remarkably parallel (for similar reasons) to that which has been reported for years at the worker level with respect to the activities of industrial and engineering staffs (cf. Whyte†). As an example, a large and successful manufacturing company discovered recently, after changing the management of a major division, a situation that company top management described as appalling evidence of fudging of production and quality data, misreporting of costs, and ignoring of preventive maintenance which had been going on for years. The relevant headquarters staff groups and even the division top staff people were completely unaware of the situation until a new line management uncovered it.

Third, staff personnel complain rather generally about their inability, without top management intervention, to get their plans, ideas, and improvements accepted by the organization. The frequently observable struggles of staff heads to achieve higher status organizationally is not motivated only by personal power needs; it is also a reaction to frustration.

Fourth, the readiness with which management curtails staff activities during periods of economic stress, and the constant and sometimes vociferous demands for "pay off evaluation" of staff programs, suggest something about the degree to which management perceives staff help as appropriate.

Finally, with respect to equitable rewards, the evidence for invidious distinctions between staff and line is to be found on every hand in relative salary scales, status, and career opportunities. A manager in a large company, during a recent discussion of these phenomena, summed up the situation in his firm by pointing out that the salary of a major staff department head (carrying a vice-presidential title) was exactly half that of his production counterpart. It was this manager's opinion that the former was more capable than the latter.

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* Chris Argyris, "Human Problems with Budgets," *Harvard Business Review*, January–February, 1953.

† William Foote Whyte, *Money and Motivation* (New York: Harper, 1955).

All of these conditions exist in a setting where specialized knowledge, skill, and service are of tremendous and increasing importance to the achievement of organizational success. In one large company today, seventy per cent of the personnel above the second level of management are staff; and with such things as the rapid growth of technology, the increased complexity of industry-government relations, and the greater concern with the human resources of organization internally and the consumer market externally, this trend is unlikely to be reversed.

Some Reasons for Difficulties in Staff Functions

Several reasons can be suggested for industry's failure up to now to achieve very adequately the objective behind the establishment of staff functions. However, it is clear that one of these is *not* the failure to observe the textbook formula for successful line-staff relations. This formula—based on the "principle" of unity of command—which dismisses the problem by denying authority to staff (but quite inconsistently awards them a major responsibility for managerial "controls") is of little help. There is at least some evidence* that friction, antagonism, and sabotage on the one hand, and effectiveness on the other, are independent of the degree to which staff groups eschew formal authority.

The struggle for power and influence, however, *is* a major underlying factor. It occurs in a wide variety of guises, within as well as between staff and line groups. It is due to the high degree of interdependence which characterizes the relationships in a complex industrial organization. Individuals are dependent on the behavior and attitudes of many other individuals for their ability to achieve both their own and what they perceive to be organizational goals. This interdependence has significant behavioral consequences.

Within any function there is dependence both up and down: up, for rewards of all kinds; down, in the sense that the superior cannot fulfil his responsibilities (and thus obtain rewards) unless his subordinates perform effectively. Staff departments, because of the upward dependence, tend naturally to be oriented toward the needs of the level (and particularly the individual) to whom they report in top management. They naturally strive to get their ideas for policy and practice accepted at this level. Line groups, made dependent upon staff actions whenever this happens, struggle to counteract what they perceive to be negative consequences for themselves. At the same time, the line is dependent in the sense that all levels need specialist help of various kinds to fulfil their responsibilities, and the normal anxiety accompanying dependence is accentuated when staff groups are not perceived as supportive.

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* Charles A. Myers and John G. Turnbull, "Line and Staff in Industrial Relations," *Harvard Business Review,* July–August, 1956.

① In addition, whenever staff groups are involved—directly or indirectly—in "control" functions, the line is threatened. As Argyris points out, staff groups exercising this responsibility (without authority, of course) readily get into the position where their rewards from above are at least partially due to their ability to find and report mistakes at lower levels of the line. This is one reason why many middle- and lower-line people regard staff "help" as a euphemism.

Finally, there is the struggle of line groups to retain their autonomy in the face of constant staff attempts to obtain standardization of procedures and practices and centralized reporting for research, planning, and co-ordinative purposes. To the line, these trends represent nothing more than the "narrow, specialized" concerns of staff groups, and the resulting necessity for conformity is strongly resented.

These represent but a few of the many forms which the "counterdependent" struggle takes within a web of intricate interdependent relationships. The interdependence represents a basic cause of some of the phenomena outlined in the first section of this paper.

④ A second cause, related to the first, is the failure of staff groups and often upper-level line to consider *who* is helped by staff activities. It is fine to regard the help as given to the organization, but if some levels or functions do not receive it, or perceive themselves to be hurt by it, the objective is not achieved.

A third cause is the failure to distinguish between unlike—and sometimes incompatible—functions which are frequently lumped together under the label "staff" in one department, and treated as though they were identical. There are at least four of these: (1) operating functions which are in fact *line* activities performed by staff groups (e.g., in-plant feeding, payroll administration, benefit plan administration, new product research, customer billing, advertising); (2) control and co-ordinating functions which are essentially policing activities over the rest of the organization; (3) auxiliary services which are line in themselves, but are highly interdependent with other line functions (e.g., maintenance, inventory control, purchasing, personnel recruitment, process engineering); and (4) specialist advice and problem analysis which are pure "staff" in the textbook sense. When, for example, activities of the second and fourth kinds are assigned to the same staff department, these people are forced to occupy completely incompatible roles. Friction and antagonism are then inevitable. Examples of difficulties in the relationships between groups carrying responsibility for the first and third kinds of functions (e.g., production and maintenance) are to be found almost everywhere.

A fourth cause is the common tendency today to place men who are capable line managers, but in no sense professional specialists, in key staff positions. It appears to be widely believed that any good line manager can head a personnel or organization planning department, for example. There is less tendency to follow this reasoning with respect to such functions as engineering, research, or accounting, perhaps because the technical aspects of these functions are more readily accepted. Nevertheless, even in such highly specialized functions as research, it is not unusual to hear at least an argument in favor of a nonprofessional head.

The difficulties resulting from this practice are many. Prominent among them are these: (1) the small likelihood that the nonspecialist will be able to provide competent leadership to his department; (2) the improbability that he will be able to serve top management in the highly important professional activity of strategy planning which involves his function; and (3) the small probability that he will have the necessary sophistication with respect to the helping role that his department should occupy.

These are among the major factors underlying industry's failure to achieve adequately the objective of providing help to the organization in the form of specialized knowledge, skills, and service.

AN APPROACH TO EFFECTIVE STAFF WORK

Let us return now to the three requirements mentioned at the beginning of this paper. What considerations should be of major concern if we realistically seek to fulfil them? Consider first the two requirements of appropriate help's being available and utilized.

It is a truism regularly ignored in practice that help is defined by the recipient. He must, in fact, be free not only to accept or reject proferred help if he does not perceive it as such, but to reject the relationship with the specialist and seek another source of help. A tough consideration in the light of current practice in hierarchical industrial organizations, surely! Nevertheless, there is ample evidence—not only from industry but from many other organizations and relationships—that help which is *imposed* on the individual is not utilized. It is resisted, and if he is coerced, the objectives of the helper are more often than not defeated. Sabotage (not to mention antagonism), in many subtle and ingenious forms, is the inevitable consequence of imposed help.

The professional-client relationship, as represented by a competent and skillful M.D. or lawyer or architect vis-à-vis his client, is a model which at first blush seems inapplicable to staff-line relationships in the industrial hierarchy. Nevertheless there are, here and there, examples of attempts to adopt the model which have been remarkably successful. Even if the full values of such a relationship cannot be realized in practice, it is possible that movement in this direction would alleviate some of the problems we now face.

It is obviously impossible to pursue the implications of this point in detail here. A single illustration may help to indicate a little of what would be involved. The client seeking professional help from an architect may have "diagnosed" his problems and needs, and have arrived at a "prescription" of the house he wants designed. A competent and skillful architect, without antagonizing (and therefore losing) the client, will help the latter examine his needs further to the point where an entirely different "diagnosis" may emerge. Moreover, the final house—not only acceptable to, but enthusiastically desired by, the client—will be in many cases entirely different from the client's original "prescription." The client would initially have resisted both the architect's "diagnosis" and his "prescription." Now, however, he feels he is being helped, and he is more than willing to pay the fee.

To draw the analogy with industry, a colleague in a large company was approached by several middle managers of a technical department who wanted a rapid-reading course provided for their subordinates. Their diagnosis: the subordinates could not cope with the materials that piled up on their desks because they had insufficient reading skill. My colleague persuaded these managers to discuss the problem further with him. In the course of the discussion they were persuaded that it would be worthwhile to undertake a more detailed analysis of the situation, and they carried it out with his help. The findings: the heart of the problem lay, not in reading skill, but in job assignments, erroneous beliefs of the subordinates about what was expected of them, and other aspects of *the relationship between these managers and their subordinates.*

The "clients" not only abandoned their original diagnosis and prescription; they involved my colleague as a helper in a rather complete reorganization of their department and a program focused on improving *their own* managerial competence.

One obvious need that would arise if the professional-client model were to be adopted, even in a diluted fashion, in industry would be for effective training of specialists (engineers, accountants, personnel administration, etc.), *at the college level,* in the skills, attitudes, and philosophy of the professional role. This might be considerably more useful, even if more difficult to design, than the conventional courses in "human relations" now tacked onto the curriculum.

Another point, already alluded to several times, relating to the problem of making appropriate help available, is the incompatibility between the helping role and the policing role involved in control activities. When these two functions are combined, effective help (defined by the recipient) is impossible.

The problem here is broader than mere line-staff relations.

Control activities have been widely used by managers in ways which vitiate their pretence of delegating to subordinates. With one hand the manager delegates; with the other he establishes a control system which enables him to check up, in detail and continuously, on the activities of subordinates all the way down the line.

Drucker's* concept of management by objectives and self-control offers a realistic way out of this dilemma. It also offers the possibility of treating subordinates as mature adults rather than as children who cannot be trusted to accept responsibility. But the adoption of this approach would require a considerable change in the attitudes and practices not only of line but of staff managers. It is perhaps more characteristic of the latter than of the former to mistrust their managerial colleagues and to develop elaborate machinery for policing their behavior. (Consider the accounting profession as an example!)

A possible way to influence staff groups to concern themselves with more appropriate help to the whole organization, rather than to the reporting level alone, would be to utilize a well designed opinion scale to determine the perceptions of all levels of management with respect to the help they are receiving from the staff. Such an instrument, used periodically, would at least reveal difficulties and problems for further analysis. It would have the added advantage of bringing the concept of accountability into some relation with specialist functions. If the objective is to provide appropriate help, we might at least begin to discover whether such help is felt to be available!

The whole question of *utilization* of staff help is, of course, closely bound up in the foregoing considerations. Help which the recipients do not perceive to be appropriate, or perceive to be a hindrance, will, as already noted, be resisted and sabotaged. There are, of course, instances (fewer than staff people believe) where line management resists entirely legitimate and necessary modifications in policy or procedure. It can at least be argued that these represent failures in the performance of the staff role (consultation, skillfully handled professional-client relations, etc.) as often as they reflect the innate stubbornness and stupidity of the line.

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* Peter Drucker, *The Practice of Management* (New York: Harper, 1954).

There is plenty of evidence concerning the successful introduction of change in organizations that would be instructive reading for some staff personnel (see, for example, Coch and French[*]). In the modern industrial organization, the objective necessity for specialist help is obvious; it will be utilized if it is "appropriate," but appropriateness involves a good deal more than the judgment of the staff specialist in isolation from the methods he uses to diagnose and prescribe for his clients. He is inevitably a "change agent," and his methods may over the long run be more important to organizational effectiveness than the nature of many of the specific changes he recommends (see Lippitt and Watson[†]).

The requirement of equitable rewards (defined again, of course, in terms of recipients) obviously hinges on the more basic requirements of availability and utilization of help. If management genuinely values the help it receives, compensation and status will be more readily adjusted. Perhaps of greater importance to staff people would be the social rewards of acceptance and the ego satisfactions of achievement which would follow in the wake of providing *appropriate* help to the organization. There is, of course, a circular relationship in this matter of rewards: so long as they are felt to be unreasonably low, it will be difficult to attract the most competent specialists and to obtain their best efforts; on the other hand, until staff groups generally become more skilled in their role relationships, management is likely to place a low value on their contribution. There is need to break into this circle at various points.

One point may well become significant to management thinking, if the professional role of staff becomes more common. This is the fact that professionals are more likely to be "cosmopolitans" than "locals" (Gouldner[‡]). Their fundamental identification is with their professional field rather than with their immediate employer. Management tends to worry about loyalties to the firm and to assume that this broader identification precludes effective performance. Also, there is a tendency to want to curtail the mobility of such people between organizations. It may be, on the contrary, that acceptance of the cosmopolitan role within the industrial complex (despite some obvious practical problems, such as those connected with annuities and other benefits) would have the long term effect of making available a higher level of talent and experience and of creating a climate in which the professional could contribute with greater effectiveness to organizational goals.

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[*] Lester Coch and John R. P. French, "Overcoming Resistance to Change," *Human Relations,* Vol. I, No. 4 (1948).

[†] Ronald Lippitt and Jeanne Watson, *The Dynamics of Planned Change* (New York: Harcourt, Brace, 1958).

[‡] Alvin Gouldner, "Cosmopolitans and Locals," *Administrative Science Quarterly,* December, 1957, and March, 1958.

THE BLURRING OF LINE-STAFF DISTINCTIONS

In the broad view it appears that the distinctions between line and staff are becoming blurred. Perhaps the most important reason is that the nature of management is changing, and the line is beginning to look more like the staff. Formal authority, the traditional tool of line management, is becoming less effective as the dependence of subordinates upon superiors decreases. Concomitantly, consultative and helping activities are increasingly seen to be appropriate within the line. These trends are more obvious within the ranks of management, but they are present in the relationship between management and workers as well.

The significant point is that the managerial job—whether line or staff—is not limited to a single role. At some times the manager is a boss in the old-fashioned sense, giving commands and telling others what to do. At other times he occupies other roles: teacher, helper, group member, expert, colleague, consultant, client. Moreover, he occupies these various roles in his relationships with superiors, other line managers, and staff specialists alike. In exactly the same way, the staff "manager" occupies a variety of roles. And, for all managers, the authoritative role is becoming more and more limited in its usefulness. Unity of purpose within the managerial organization is more important than unity of command.

One consequence of these trends is the greater significance of the managerial *team* at each level of the organization. Much of the manager's work—be he line or staff—requires his collaboration with other managers in a relationship where personal authority and power must be subordinated to the requirements of the *task* if the organizational objectives are to be achieved. Effective collaboration of this kind is hindered, not helped, by the traditional distinctions between line and staff. The goal is to utilize the contributions of all the available human resources in reaching the best decision on problem solutions or action strategies.

The modern industrial organization is a vast complex of *interdependent* relationships, up, down, across, and even diagonally. In fact, the interdependence is so great that only collaborative team efforts can make the system work. It is probable that one day we shall begin to draw organization charts as a series of linked groups rather than as a hierarchical structure of individual reporting relationships.

INFORMATION TECHNOLOGY AND LINE-STAFF RELATIONS

What are the implications of the burgeoning field of information technology with respect to these general considerations concerning line-staff relations? What will be the impact of these new developments upon the organization? Will information technology intensify or alleviate the problems we now face in this field?

The answers to these questions are not at all clear. A major factor in determining the outcome will be the sophistication of company management (particularly the specialists who head this function) in planning the strategy for the development of information technology in their organizations. Several alternatives seem to be possible. Perhaps the issues will be clarified by considering two extreme ones.

1) It is possible that information technology will be incorporated into the organization as one more traditional staff function (perhaps collecting, along the way, existing activities like industrial engineering, production planning, inventory control, purchasing, etc.). It will, in this case, be called staff, denied formal authority, but given major control responsibilities. The department will report

close to the top of the organization, and there will be a large headquarters group of specialists involved, perhaps with divisional groups reporting to it.

If this is the direction taken, it is not difficult to foresee the usual costly consequences. There will be intense undercover struggles for power wherever this function creates interdependent relationships (and this means throughout the organization, because information technology will affect every other function). Help given to the upper levels of management will often be perceived as a threat by lower levels, and the familiar consequences of resistance and sabotage will appear.

The information technologists will feel that they need to standardize a vast number of operating activities and to centralize them at headquarters. They will see themselves as taking decisions away from middle and lower management, and they will see the operating organization as being increasingly controlled and directed by centralized computer programs. They will brush aside arguments concerning the unique circumstances at the local level with the certainty that these can all be foreseen and built into the program.

Along with these things will go the familiar characteristics of bureaucratization: living "by the book," passivity in the face of massive red tape, leveling downward of the quality of middle- and lower-level personnel, intricate protective machinery of all kinds, inefficiency, and waste.

Finally, one may expect to hear from the staff the justification that their analyses clearly indicate what is good for the organization, and that operating management must be made to comply in order to gain the demonstrable economic advantages that information technology offers. In fact, this whole approach rests heavily on a paternalistic philosophy one which, however, is least likely to be recognized by those who practice it.

2) At the other (and equally unlikely) extreme, it is possible that management will incorporate the specialists in information technology as part of the management team, rather than as a separate staff function of the conventional kind. It is possible that the specialists will have a sophisticated conception of their role as "change agents" in the organization, and that they will view their strategies of change as basic to their ultimate success. In this case,

they will take great care to provide help not only to the top of the organization but to all levels.

The course which information technology will take will be sharply different in this case. Instead of taking decisions away from middle and lower management, it will attempt to provide data which increases the certainty of decisions, to help operating management free itself of much routine paper work so it can devote itself to the significant aspects of managing.

There will be recognition that local conditions are unique, and provision will be made for the necessary local autonomy. Standardization of procedure will serve local as well as headquarters needs, and the necessary flexibility will be built into the programs. Although many operations will be centralized, the process will be selective, and the outcome will be *increased* local autonomy in certain important respects.

There will be a clear recognition that the specialist staff has an educative role to play, and that this is incompatible with the paternalistic "I know what's good for you" attitude. Operating managers at all levels will participate actively in bringing about the development of information technology; they will influence the nature as well as the strategy of the changes that occur.

This approach will not, of course, eliminate difficulties. There will be substantial reallocations of managerial manpower, and these will present serious problems. As managers are freed from many routine duties it will be possible to widen the span of control, and flatter organizational structures will result. Along with such changes will come a different conception of supervision, a pressure for more effective delegation, a series of problems concerning the way in which "controls" are administered. However, the general trend will be away from increased bureaucratization and toward the fuller utilization of managerial potentialities.

In contrast to the paternalistic philosophy of the first alternative, the specialists in information technology will have a "helping" philosophy; they will establish a professional-client relationship with all levels of the organization. It is unlikely that change will proceed as rapidly as in the first case, but over a decade the accomplishment for the organization may be substantially greater.

It is, of course, unlikely that either of these alternatives will resemble closely the reality that will emerge as information technology becomes incorporated into modern industry. Pointing to them serves to indicate, however, that the consequences of these new developments will be important, and that the economic gains achieved may depend heavily on the philosophies and attitudes of management with respect to the strategy of incorporating information technology into the organization. In this case, surely it will not be sufficient merely to add a new box to the organization chart and to issue some new position descriptions.

COMMUNICATION AND ORGANIZATION

By

Alex Bavelas[*]

WHEN A JOB IS MADE UP of separate parts, and the parts fit together, small errors accumulating in the different parts may easily ruin the final product. Any beginner in woodworking will attest to that. He learns early, and often sadly, to study his plans and consult them frequently, to work slowly, and to check his measurements.

When the interdependent parts of a job are distributed among many different persons, all of the usual problems remain and new ones appear. The new problems stem from the nature of distributed work.

A single workman who finds that the interlocking faces of a joint that he is building do not quite match will decide which face to modify or will scrap them both and begin again. When two men are involved, questions may arise as to which one of them will make the adjustment, and which of the two of them was in error. When work is distributed, such problems are always latent in the relationships among men and functions. And the more a job is fragmented, the more numerous and the more difficult these problems may become.

Difficulties of this kind may be serious even when the working group is quite small. Not every enterprise that starts with five men in a rented garage grows to brag about its origins, and one common reason for failure is that the problems of effective combination are not solved. But as the group of persons involved grows bigger, questions of co-ordination quickly become crucial, and their treatment is one of the traditional tasks of management.

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In recent years, one aspect of this management task—communications—has been singled out for special emphasis. A great deal has been said and written about the role of communication in the managerial process, and most often, it has been treated as a "problem": a human relations problem, or a psychological problem, or a problem in language and social skills. Psychologists, especially, have taken the lead in pointing out the importance of communication in interpersonal relationships. The psychological approach has been popular. Business managers have not only accepted it, they have encouraged it.

The argument that can be made for the relevance of the psychological approach to organizational communication runs this way: The social structure of any hierarchical organization ultimately reduces to a question of personal relationships among superiors, subordinates, and related staffs. These relationships, if they are to work properly, depend upon appropriate and effective communication. And the quality of interpersonal communication depends, in turn, on the psychological situation in which it takes place.

This approach is essentially clinical. Its great strength is its ability to "explain" difficulties between individuals, and, since such difficulties are invariably reflected in the communication process—either by expression or suppression—the communication process is naturally included in the analysis.

Quite understandably, the recommendations that typically emerge from this approach have emphasized the improvement of the individual as "communicator." Thus we find the current emphasis on better speaking, faster reading, better listening, more effective group discussion leadership, and, of course, better psychological understanding of one's self and of the other person.

One cannot quarrel with these recommendations. But there is the question of whether the emphasis on the individual and his local communication problems has not obscured the more general problem of the communication system itself: its properties as a system, and its relation to other aspects of the managerial task. Also, the question arises of whether the "personal problem" emphasis has not helped to obscure an important distinction between communication problems and problems which have their origin elsewhere but which are symptomatically expressed in the communication process. When this distinction is lost, there is always the possibility that the treatment of symptoms will be substituted for direct action on the essential source of the difficulty.

For example, let us consider the case of Jack, a high-school boy, who has a summer job washing the windows of a very large old-fashioned house. The lady of the house is elderly, very dignified, and rather intimidating. She wants all of the windows of the house washed every other week, *but only on the inside.* On odd weeks, a man with a ladder washes the windows on the outside. This is a job that Jack finds very hard to do well. When he does the windows, the outsides of the panes are never clean. His most vigorous efforts lead to no perceptible improvement. Jack gets little satisfaction from washing a window that looks as dirty when he has finished as it did when he started. His morale and the quality of his work slide slowly downward and, in compensation, so does his opinion of his employer. Communications between Jack and the lady of the house become increasingly strained, and by the end of the summer the relationship is terminated with mutual relief.

It is quite in keeping with current fashion to analyze this situation as one of communication failure. Why did the employer not make an effort to find out how the employee felt about the job? Why was the relationship such that the employee could not simply explain his problem to the boss? Why did the boss not have a discussion with the employee when he hired him so that they could have reached a joint decision to wash only the insides of the windows?

The major objection to this line of analysis is that it neglects the fact that the difficulty in the situation had its roots in a poorly conceived job assignment. One may argue rightly that the harmful consequences of poor organizational arrangements may be significantly lessened by the right kind of individual training in communication techniques. But the question being posed here is not whether operational discomforts can be alleviated by the training of individuals. Very probably they can, up to a certain point. The question is, rather, whether symptomatic communication difficulties can be eliminated by radical organizational action.

What is being proposed in this paper is that organizational communication systems be considered in their over-all structural aspects as well as in their local psychological aspects; and that their development and elaboration through time be viewed as an adaptive response to organizational requirements.

All industrial communication systems are relatively highly centralized. That is, information about the states of different parts of the total organization is gathered at central points where it is analyzed and where decisions are made.

It will be useful for the purposes of this discussion to assume that all modern industrial systems have descended from a common, and quite possibly mythical, ancestor—the extreme form of "one-man rule"; and that the departure of modern systems from this stereotype of complete centralization is the result of modifications which have been made in the effort to avoid some of the difficulties inherent in completely centralized human systems.

What are some of these inherent difficulties, and how have modern organizational forms evolved through adjustive responses to them?

The completely centralized authoritarian system was based on the notion that, if one knew in detail the job that had to be done, one could derive the appropriate organizational actions. Subordinates in such a system were considered primarily as agents of execution. Ideally, one needed only to give them the proper orders and instructions. Thus the manager's essential problem was to derive from the nature of the task before him the appropriate set of commands.

In practice, as every manager who tried to operate in this way discovered from experience, things never worked so simply. Departures from plan as the result of unpredictable changes in the situation and as the result of human unreliability and imperfection were frequent. Thus, in addition to giving the logically required orders and commands, it was necessary to know what the actual state of affairs was at the various points of the organization, so that corrective actions could be taken.

The structural properties required of a communication system under this conception of management are clear: it should be highly centralized, and it should allow orders to go down and reports to go up.

In the extreme instance, such a communication system would center upon a single person who would retain complete authority. He, on the basis of the detailed information coming in from all the outlying parts of the system, would make decisions as to the best use of available resources in terms of the current state and the objectives to be attained.

The best that can be said about such a system is that it appears uncomplicated. In an organization of any size it is almost certain to be unworkable, except at enormous cost. If the system were actually used as described above, the amount of detailed information that would pour into the decision-making center would literally be overwhelming.

It is typical, and not surprising, that men who have persisted in trying to operate a "one-man rule" system usually claim extraordinary capacities to assimilate information and to make decisions. It is commonly assumed that this conviction of personal superiority explains the predilection in such men for complete and autocratic control. It should also be considered, however, that once a system, for whatever reasons, is completely centered around one's personal actions, it may be necessary to believe in and to claim a personal superiority sufficient to validate such an arrangement.

But despite any such (real or imagined) superiority, a single man at the center of such a communication and control system would be seriously overloaded.

He might, of course, do as many others in such a situation have done: essentially, ignore the information collected and rely instead upon intuition, or upon esoteric theories uncontaminated by facts, or even upon magic helpers like astrology and divination. This seldom means that he will relax his demands to be completely informed. There is likely to be a continued insistence that the data be collected. Used or not, an accumulating bulk of records appears to have comforting and reassuring properties.

But if the man at the center were to try to use the information being gathered, the overload would surely lead to punishing delays. In many parts of the organization the decisions and authorizations required before action could be taken would arrive too late to be effective, and the local person would be faced with the unhappy alternatives of acting on his own discretion (a course not likely to be rewarded, even if successful, in a thoroughgoing autocratic set-up) or of allowing opportunities to pass without response.

One way to try to overcome overload and delay would be to specify as many operating decisions as possible in advance, and to lay very great emphasis on the importance of carrying through all directives exactly and without failure. This would allow the decision-making center to proceed with assurance even before confirming messages had been received that the job had been done. And, perhaps more important, it would eliminate the need for corrections and modifications of the original plan because of purely local and individual perturbations.

These two conditions, aimed at relieving the condition of overload at the center, produce a completely rigid autocracy. The "decisions in advance" become inviolable books of rules whose size and specificity grow endlessly and, of course, fruitlessly. It is impossible to specify with anything approaching completeness the variety of problems that may have to be faced in organizationally outlying sections. To do so, one would have to be able to predict accurately the events which would occur, or be able to control the environment in which the organization had to operate. It is interesting to observe the attempts to institute wide-spread control of the operating environment, and claims of the ability to predict the future have been made with regularity by most of the "pure" autocracies that have existed.

The effects of all this on the person far from the center of control and low on the hierarchical ladder are clear. Situations will surely arise which are not covered by his book of rules. Since local initiative is discouraged, he may follow one of two courses. He may ask for special guidance and hope that the delay in receiving it will not be so great as to result only in embarrassment—an outcome that might attract undesirable attention to himself. Or he may learn to avoid or simply not to see situations that are not "in the book." If, on occasion, he should dare to deal with some local problem on his own discretion, he will probably choose not to report it, whatever the result. Thus any know-how that might accumulate at the periphery would probably remain trapped there. Performance reports, in such a system, would become largely verifications of the correctness and the wisdom of the decisions being made at the center. The man at the center, on whom everything depends, would find himself in the precarious position of knowing less and less about what was really going on, and this would lead to the setting up of special and just as autocratically controlled communication systems for ferreting out and reporting what was *really* going on.

But such a progressive convolution of autocracy is not the only path that can be taken in attempting to avoid the problems of overload and delay. A different and more prevalent method is to set up a filtering system intended to relieve the actual load at the center by pre-selecting relevant information and putting it into condensed form. Such staff work is often represented as playing no part in the actual making of decisions. Such arrangements, however, if they are to offer substantial relief, must allow the staff to exercise discretion. And quite commonly such staffs, as they become more helpful and more specialized, are entrusted with more and more discretion. It follows from the strategic position that these staffs occupy that even a little influence can easily be built into more. And it is not surprising that arrangements like these are frequently viewed with mixed feelings by the very persons whom they serve. Although they are usually created to facilitate communication, it is not uncommon to find that at lower levels of the hierarchy they are regarded as barriers to communication rather than as helpers. For if the man at the center—unassisted—had to ignore certain data because he was overloaded, the special staff might just as often ignore it because it is not appropriate to the system it has devised and which justifies its existence.

To take a simple example, in a large organization an extreme centralization of the personnel function often tends toward the development of a detached, impersonal, "objective" view of human beings. Otherwise, the functioning of the personnel staff would be hopelessly complicated by the many unique and changing facts about individuals with which it would have to deal. Decisions from central personnel, if such details are ignored, are enabled to be more general and to fit the "employee," but are only accidentally appropriate in any particular case.

The use of staffs in the attempt to deal with the communication load and still retain control at the top has been carried to extremes in some large organizations. It is, of course, organizationally self-defeating, and the greatest ingenuity is expended in justifying the procedure by the invention of job titles and the drawing of visually logical-appearing relationships on the tables of organization. Nevertheless, the common experience of many companies is that all such interposed staffs tend in the end to lengthen and to complicate operational communication lines, and that they result in the creation of at least as many new problems as those which they presumably solve. But the essential criticism is that in such arrangements a considerable degree of control tends to pass from the "top" to *staff* entities rather than to subordinate *line* managers.

The significant attempts to cope with the problem of overload and delay have been those based primarily upon the downward delegation of responsibility and authority for making decisions. These attempts have been of two kinds: those which are, in principle, filtering systems operating largely within the line structure rather than through staffs; and those which are not so much filtering systems as they are reorganizations of the total enterprise into relatively autonomous and self-contained units.*

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* There is a third "variety" which deserves peripheral mention. In recent years there has been a widespread advocacy of managerial methods commonly labeled "democratic" and generally oriented toward a degree of participation by the led, in the process of direction and control. The question of the essential soundness of democratic methods in management has been the subject of a continuous (although, more recently, not always audible) debate. Fewer and fewer managers are championing the "good old no-nonsense way." Not so much because the superiority of the old democratic method has been proved, but because the authoritarian way has become unpopular and is generally socially disapproved. The manager who persists in protesting against giving up the traditional perogatives has little defense against the charge that he is "rigid," or "power-oriented," or "authoritarian." Wearing these labels, anything the resisting manager may say merely constitutes additional proof of his backwardness and damns him further.

Popular though the idea of democracy in management has become, not all of those who advocate it have the same thing in mind. Some of the most vigorous decriers of the authoritarian manager who would openly control his subordinates by explicit means, go to great lengths to prove, curiously enough, that their

The first of these approaches is well illustrated by companies which are organized as a set of vertical functional systems. In theory, this form of organization should bring two kinds of relief. The "top" man may now deal with competent and responsible condensations of data from a small number of subordinates who serve as managers of the separate functions. They, in turn, are free to devote their efforts to the special problems in their domain—finance, manufacturing, sales, engineering, et cetera. In many instances, however, this relief is bought at a very high price, because the effective and efficient operation of such a system of separated functions demands a quality of co-ordination at the various levels among the functions that may be impossible to achieve.

An obvious reason for the great difficulty of co-ordination is that such functions are not so separate in fact as they might appear on paper, and many of the processes vital to the enterprise as a whole fall squarely in areas of overlapping concern and responsibility—no-man's-land. Another reason for the difficulties that are experienced is that the identification and separation of functions are usually made along lines that are more traditional than pertinent. It is not absolutely clear that the customary functional divisions are best for any particular firm. But for most managers who learned their trade in traditionally organized companies, or who were educated in business schools in which the same cate-

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"democratic" methods can lead to even broader and more pervasive control over individuals and groups. Their claim, quite simply, is that the manager who is well schooled in their methods may not only control his subordinates, but do so in a way that avoids the backlash of resentment and counter-aggression that inevitably follows overt coercion. These methods of exerting influence are said to be so subtle that the manipulated persons remain unaware of them. This approach has its attractions. To the manager who would like the "human relations" benefits of participation but who is reluctant to give up control over its outcomes, it promises that he can have his cake and eat it too. At a recent conference, a young manager described in some detail the refinements of technique by which he claimed to be able to evoke from his subordinates "in free and permissive discussion" precisely the decisions he wanted. He concluded, "The important thing is that they get the *feeling* of having participated, even though the decision had really been made by me."

Let us grant that such techniques may, so long as the deception succeeds, gain their objective. But at what cost? Is everyone in the management group indoctrinated in these skills? Is there a gentlemen's agreement not to use them on each other? The young man just quoted disavowed the use of such tricks on any but the "lower" levels of management, presumably the ever-suffering foreman. This disavowal only makes the entire conception even more unpalatable. *In contrast, the harsh and undisguised authoritarian stands a frank and honest fellow.*

gories were used to separate courses and "fields" of specialization, the mental set is very strong indeed.

It is not difficult to show in particular companies that the usual functional separations may require more, and more accurate, intercommunication than other less common and, in appearance, less elegant arrangements. A poor definition of functions in this sense not only increases the direct load of time and effort needed to co-ordinate operations; it also indirectly increases the time and effort needed to unsnarl the consequences of errors or failures of communication.

One result of such experiences has been an increasing movement toward the second approach and the adoption of some form of decentralized operation. In the decentralized organization, by the creation of relatively autonomous subsidiary centers, the length of the communication lines serving each of them internally is greatly shortened, the total load of communication within each of the decentralized units is lightened, and the delays attending "top"-management decisions are dramatically shortened and, in some instances, depending on the precise corporate structure, many customary delays are eliminated altogether.

But although the appeal of decentralization is largely due to its promise of more flexible and effective controls, the benefits that have been claimed for it take many forms: more rapid learning from experience, quicker and more effective use of new ideas, improved morale, a greater sense of responsibility, more opportunities for the development of managerial talent. It is likely that some of these benefits result from the fact that time and effort are released to deal with the problems inherent in the business at hand instead of problems which are artifacts of an unwieldy organizational structure.

Since World War II, there has been a rapid development of theory and the technology of data processing. Today, families of devices exist which vastly extend our former capacities for the rapid and accurate handling of data. What it is possible to do in this direction and what it is reasonable to hope for in the immediate future will be discussed elsewhere in this symposium. But against the framework developed in this paper, some questions about the impact of these new data processing facilities on human organization are pertinent.

The attractiveness of these machines to the business manager, at least when he views them from a distance, is undeniable. Any executive who has been burdened with floods of material to read cannot but be impressed by such statements as "an electronic computer using magnetic tape can read *Gone With The Wind* in four minutes." It is not hard to understand his excitement at the prospect of "new and never before available data" about his operations. This is heady wine, and one may easily lose hold of the essential issues.

> One sales manager who found out what a high-speed electronic printer could do eagerly had one installed to give him a monthly breakdown of sales. The report, duly prepared each month, was so voluminous it had to be wheeled in to him on a dolly.
>
> A man who asks for a monthly statement of specific purchases by 35,000 customers, as one division manager of a chemical company does, may read scarcely any of it, but he continues to want it.
>
> The president of one large chemical company demands a report on his company's sales three times a week, and he is so impatient for this information that a messenger is assigned to wait beside the duplicating machine in order to rush a copy of the report upstairs to him.*

Misconceptions about the appropriate use of these new devices and excesses like those quoted are to be expected. Every technological advance has led to preliminary nonsense of this kind. Already the balance is shifting, and one may find more and more effective employment of data processing systems in industry.

The interesting questions arise when one asks how organizations will be affected when these machines are used, not to duplicate existing processes faster and more accurately, but in those ways which take full advantage of their peculiar capacities: not "Will management return to centralized control again now that there is adequate information-handling capacity?" but "Given such information-handling capacities, what organizational forms are appropriate?"

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* Perrin Stryker, "What Management Doesn't Know Can Hurt," *Fortune*, November, 1957, p. 286.

It was argued above that the elaboration of communication and control systems, whether by the proliferation of special staffs, or by detailed downward delegation of the responsibility and authority for making decisions, or by decentralization, has been motivated by the need to find ways in which the human limitations on dealing with great volumes of information speedily and accurately can be overcome. Until the recent past, the major advances in this quest have been organizational—attempts to organize people and work in such a way that some practical match could be obtained between the data processing that had to be done and the human capacities to do it.

In the attempts to solve this problem, two kinds of concessions have been made as a matter of course: less has been asked of the data than might have been, and the answers to the questions asked have been accepted with suitable margins for human error. This compounded uncertainty has been accepted as a basis for operations, because to have demanded much more might have meant getting much less.

Many time-tested organizational procedures have evolved in response to precisely this continuing informational uncertainty, and their validation in practice rests on the fact that they serve to compensate for the continuous error in the system. To the extent that facilities for the handling of information improve, many of these compensatory procedures will become less meaningful and perhaps even deleterious. But habit, training, and emotional investment will make changes difficult. The lady who didn't approve of stained-glass windows defended her opinion by saying that she liked her "glass the way God made it." In the same way, many will feel that the threatened practices are not "temporary buildings" but rather the "true architecture."

PART IV

Information Technology: Experience in Five Companies

"The rate of progress of information technology in American business will be partially a matter of technological feasibility and partially a matter of economics. There is a third barrier—and an important one—which must be hurdled. This is the barrier of human acceptance."

THE INTERNATIONAL SHOE COMPANY

By

Leonard F. Vogt[*]

For the past five years we have been living in a business world in which the organizational structure is rapidly being changed. Some five years ago the first electronic computer was brought to bear upon business problems. It was with this significant step that a new era in a changing business world was begun. Germination of the idea of data processing has taken place, and the sprout has pushed its way through the surface. It will be some time before we see this creation in blossoming maturity. With no experience in this area, we can only speculate about the time it will take to mature and about the size and character, in the mature state, of that which is already growing.

Time, the effort we give to the problem, and the climate in which it must grow, will all play parts in its final form—if, indeed, it ever becomes final. This is the propitious time for us to examine that which is already with us, in order to determine to the best of our ability what our creation is likely to be and what its probable effects will be.

It is not at all difficult to conclude that the basic functions of sales, procurement of materials, personnel management, production, marketing, financing, and accounting will be strongly cemented together by an automated data processing system which is unlike anything in existence today. The character of these functions will be altered by constant exposure to the pervading data processing system, which will tie them together more closely than ever before and will make each function more sensitive to the conditions of the others.

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It seems a certainty that, under the impact of automated data processing, many of the ratios of costs of doing business which were heretofore accepted as standard and normal will be upset, and that substantially reduced costs will be possible in areas where costs had been considered irreducible.

Many of the complex decisions, which presently are made upon judgments, will be reduced to relatively routine decisions when viewed from the frame of reference of the facts which will be available upon which to make them.

Decentralization, which in many instances has been brought about for the purpose of meeting problems more quickly through working with smaller, more intimate units, will no longer be necessary for that purpose; but decentralization for other reasons which are not yet identified or which are deemed impractical today may become a reality.

Automated data processing will enable the large business of tomorrow to be handled with something approaching the ease and facility of handling the small one-man business of yesterday.

Communications within each company will be sure, accurate, and fast. A new group of men, understanding how effectively to design an automated data processing system and knowing how to use electronic equipment most effectively, will come to the fore, occupying positions equivalent to those in sales and production management.

While there has been much development toward these ends in recent years, only a bare start has been made. It seems likely that with present technological development it will take some twenty to twenty-five years to reach a leveling-off point where a type of semi-stability in organization will set in, similar to the one we have had for perhaps the past fifty years but at a much higher state of development. Automated data processing will be linked directly to automated production. There will be little distinction between what is office and what is plant. Departments as we know them will almost disappear as the more tightly knit business entity emerges.

At International Shoe Company, the decision to use an electronic computer was motivated by a cycle of increasing inventories of finished goods, increasing markdown losses, diminishing service to our customers, and other undesirable trends. It was apparent to all who had been connected with the shoe business for some period of time that these conditions were related to changes which were occurring within the industry.

Innovations in styling, an important element in our business, were taking place; but instead of new styles and patterns replacing the old, there was a distinct tendency to add them to the already existing styles. The result was a diminished volume per style. This, in turn, created inventory and production problems, which in turn brought about rising costs.

Much of the same kind of activity was also occurring in the material field. A great variety of new surfaces and colors were introduced to the shoe business that, when, added to those already being used, resulted in a literal riot of selection. This had the same effect and was, in fact, compounded with the effect of the changing style picture.

Furthermore, it added a factor of obsolescence of raw material and, conversely, created conditions predisposed to material shortages. These material shortages imposed hardships upon production, thus lending impetus to the cycle.

In 1954 it was decided to undertake a study to determine how these new conditions could best be managed. The study resulted in the conclusion that the chaotic material, style, and production condition had to be met in a forthright and direct manner.

Each department and operating division of our company had taken its own intradepartmental or intradivisional steps to deal with the recognized conditions. Our merchandising people, who are responsible for having the right stock in the right place at the right time, were tending to lead in their placing of factory orders, in anticipation of, and in an attempt to lessen, production delays which they felt sure would occur.

The various merchandising divisions attempted to inform our several procurement departments about their thinking. But, since each merchandising division was operating on a different basis and, consequently, made its estimates in a different manner and covering a different period of time, our procurement departments had great difficulty assembling the information in an understandable form. As a matter of fact, when we examined the situation closely, we felt it was rather amazing that they could use the information at all.

Since it was such a difficult problem to assemble and interpret the information, the procurement departments tended to make their own estimates of what would be required. This added confusion to the problem, because the thinking of the purchasing departments was not necessarily geared to that of the merchandising divisions.

Simultaneously, the production departments, faced with similar problems, were making independent estimates in a similar way. Consequently, each of the major internal divisions, while attempting a degree of co-ordination, was unsuccessful in this because each was second-guessing the other; and it was only in the areas where they all, almost coincidentally, saw things in terms of the same volumes and timing that the deliveries were good. There was a large fringe, however, where they did not see things the same way, resulting in a bad lack of co-ordination.

This, of course, caused obsolescence of material on one hand and shortages on the other. This resulted in a conflict between the desire to make shoes and the inability to do so because we had deficient production capacity in some areas, or because we had the capacity but did not have the materials in others. This lack of co-ordination began insidiously and in a very minor way, but it was gaining momentum at a startling rate.

The result of our study was the recommendation that the company proceed immediately to establish a system of sales estimates. This system, after being adjusted for inventories and other conditions, would be the basis for a vigorously controlled plan to project and anticipate the coming season's business so that detailed merchandising, procurement, and production plans could be laid. The idea, of course, was to recognize potential problems and to take steps to eliminate or mitigate them before they became real problems which tied up the production, resulted in excesses, or had other detrimental effects.

At the same time, the study indicated that, until such a system was established and until we were able to standardize, there would be no point in bringing in a computer to handle the detail, since the computer could not possibly run in nineteen different directions at the same time. As the problems of co-ordination were being studied, it became generally recognized by our management that, in addition to the changing nature of the shoe industry, our company had a problem resulting from its own organizational structure.

International Shoe Company was founded in 1911 by the merger of the Roberts, Johnson and Rand Shoe Company and the Peters Shoe Company. Each of these companies manufactured general lines—that is, men's, women's, and children's shoes of all types, ranging from the most utilitarian men's work shoes to the highest styled women's dress shoes. Each operated a number of shoe factories. A short time later the Friedman-Shelby Shoe Company, another general line manufacturer, was acquired by purchase.

Corporate growth took place through the 1920's and 1930's through the acquisition of additional shoe companies by purchase and through the formation of separate additional selling divisions to meet specific conditions. During this period, the production facilities were brought under centralized control, as were a number of other departments; but, for the most part, each of some nineteen selling divisions operated as an entity—with consequent duplication of organization, personnel, and services but, at the same time, with different policies, execution of policies, and techniques in handling the details and rendering the services.

This worked satisfactorily and profitably during the years when the shoe business remained relatively simple. As the business itself became more complex, the organizational structure could no longer manage efficiently the complexities imposed by the changing business. It became apparent that steps had to be taken to centralize, simplify, and streamline the organization, and that these had to be taken with or without the study of operating details which was being made.

From 1955 to the present we have engaged in changing the organization, which has resulted in much more centralization. This centralization in itself brought about standardization in principal areas; and, as a result of the detailed study of internal operations, direct steps were being taken to standardize the detail procedures within newly established centralized organization. By October, 1955, our thinking had advanced far enough along this line for us to know that sufficient standardization would take place to make a computer's effective use possible; and the time between then and January, 1957, when the computer was received, was devoted to effecting the necessary changes.

Our thinking is that changes brought about in the organization —the centralization and the standardization—would in themselves accomplish much toward the end we are seeking; but a computer as a tool with which to handle the vast and growing detail is an important part of the plan, and with this tool we can make the newly centralized organization even more effective.

Our thinking goes beyond the point of looking upon the computer as a statistical device. We feel that the computer has become somewhat symbolic of what we are trying to do and that, in establishing the flow of work from the various departments into the computer and from the computer to the next department in line, we have developed not a service department, but an effective link in the line of production. Even more important than that, we will reach a stage—and are, in fact, at its threshold today—where we can automate many functions presently performed through interpreting reports. Some persons consider paper to be the final output, but we view its production as being only an intermediate stage.

To reach our present state of development we had to go through the usual steps of determining what we wanted to do, in what areas we could most effectively work, what hardware would best suit our needs, and whether this was economically feasible.

While going through this period, we kept in mind the fact that an electronic computer offered, for the first time, a chance for true integrated data processing. Consequently, we ruled out any single application, such as payroll or accounts receivable. We decided that the computer could best be used as an instrument of communication and co-ordination, flowing work from one job to the next, and that it lent itself not only to straight sequential processing but to a complex network of applications which reflects the impact of each transaction in each area upon all other areas.

Our decision was not difficult because it was obvious that the computer could best be used in our business for relating sales to inventories of finished goods, for converting basic sales estimates into estimates of raw materials and estimates of labor requirements by operations and machine, for calculating raw material requirements, and for setting up production schedules. In fact, it appeared that a computer would be misused if assigned to any lesser problem than these. Therefore, we eliminated from our first consideration anything outside this area.

Oddly enough, even though we operated under the direction of the Comptroller (now Treasurer) of our company, no accounting or fiscal applications were considered for the earliest work, although they will be included in later stages. We felt that the computer, and more specifically the program it represented, would make a major change in our company, and that real dollar value would result from proper application, which would reduce investment in inventories, both in finished goods and goods in process. At the same time, it improved our service by insuring adequate stocks of vital shoes; by reducing the number of manufacturing days in process through staying within production capacities; by having raw materials when needed; and by reducing the losses resulting from obsolescence of raw materials, merchandise markdown losses on finished shoes, and the loss through customers' cancellations of orders which we were unable to fill. A modest improvement in any one of these factors will produce major dollar savings—to an extent that makes savings on a single application (such as payroll, where the best effect possible would be the production of a payroll of the same value at—perhaps—slightly less cost) pale and almost insignificant by comparison.

As a matter of fact, if viewed in its proper perspective, change in the areas that we considered is literally changing the historic balance sheet and profit and loss ratios which were considered normal. This is significant, for until a computer and the plan that it symbolizes could be brought to bear, industry had established ratios based upon another way of doing business. These ratios will change, and it is this change in ratios which will bring about almost unbelievable reductions in the normally accepted costs of assembling materials with the use of labor to produce a product. As this change gradually unfolds—and it is certain that it will—significant changes will also take place in corporate organization and in the functions of the people who are represented.

It was obvious from the very beginning that the use of the computer, whether in single applications or applied to something more worthy of its capabilities, would tend to strike significantly at clerical areas. It is quite common in some companies whose computer has been limited to a single application for substantial clerical savings to be made, and that, doing job for job on the computer versus on punched-card machines and/or manually, the computer might be paid for on a dollar-for-dollar basis. These, of course, are direct savings, and in some industries the presence of a computer has been justified by figures of this kind.

No one can quarrel with that kind of justification, provided that the concept of computer use does not stop at that point. If, however, the computer is extended to integration of applications, the impact extends into higher and higher areas of activity, depending upon foresight and upon the degree to which the computer facilities are used.

On a single application—simply doing on a computer what people formerly did—there is a personnel replacement; but, as an integrated system is developed, the computer becomes a means of communication and a means of standardization, and the departmental walls come tumbling down. As this occurs, the duplications of effort that take place at the output level of one department and at the input level of the next tend to merge, and half or more of the work in these adjacent areas tends to disappear.

Advancing the use of the computer tends to lead to developing statistics in areas where they could not be developed before, because of a lack of clerical help or the inability to assemble a large enough force with consistent enough performance to gather the information in time for it to be of value. When these areas are invaded, no additional clerical help is released because none had been used; but new statistics develop that must be interpreted to be effective. Consequently, new skills must be developed, not in the clerical area, but at the next echelon above. In this echelon are the people who, in pre-computer systems, took statistics developed by the clerical staff and derived from these statistics information which led to formulation of operating decisions.

Integration stops and automation begins when, instead of voluminous statistical reports being turned out by a computer, the information is retained in the computer and the computer itself is called upon to do the calculating and to make decisions based upon its calculations. At this point, there is a distinct invasion, if not an obliteration, of low-level management or technical skills. However, when these jobs are invaded, there is usually some element which is not purely statistical or calculating by nature but which involves some degree of artistry. It seems inevitable, then, that as the work of a group of persons at this level is absorbed, there will remain an untouchable core that must still be done by low-level management decisions. Since this is generally a more difficult area than the purely clerical one, and since much of this work can be done with fewer hands or, more realistically, heads, after the elimination of the calculating and most decision phases, the tendency must be to upgrade those people who remain to do the artistry phase of the work, and their decisions in this area will have a greater impact. For example, in our business our inventories are controlled by merchandising men. These people possess a unique combination of talents, ranging from a “sixth sense” about what kind of shoes your wife will want to wear next year to a proclivity for quick and accurate handling of the analysis of a multitude of statistics.

A computer will tend to eliminate from this job the statistical analysis phase, which constitutes perhaps eighty-five or ninety per cent of the work. The ten to fifteen per cent remaining is this “sixth sense” and things relating to it. Therefore, it seems inevitable that the character of this work will change. More emphasis will be placed upon the individual’s decisions to determine those things which require his skilled attention, selection, and estimates, and less and less upon his ability to analyze figures. The time saved can be used to sharpen his skill by exposing him to more customers and giving him more on-the-scene observations of those things which cannot be readily reduced by calculation. This same thing takes place in many lower-middle management, administrative, and technical jobs.

Consequently, it must be considered that the number of persons engaged in this kind of activity may decline over a period of time, but certainly the work will change complexion. The men of this level in the future must possess a higher degree of skill and, as a matter of fact, must be endowed additionally with new talents and/or training to live with, to fit in with, and to be a part of the new scheme of things.

Somewhat associated with this is a trend taking place in decision-making at the level immediately above the group just discussed. Until the advent of the computer concept, a man of intelligence, balance, and experience was necessary to make decisions based upon the facts which could be accumulated. Very often these facts were late because of the difficulty of assembling them, inaccurate because of the systems by which they were assembled, and incomplete because of the limitations that existed in fact gathering. A gap existed between the condition indicated by the available data and the decision which was made through intelligent interpretation of the facts.

With a properly programed computer, it is possible to assemble more facts more quickly and more accurately; more important, it becomes possible to make many of the analyses that intermediate management would make. These can then be presented to upper-middle management with statistics which are so complete that the required lines of action are explicit; what is left is really no decision at all, but rather a recognition of what obviously must be done. In many instances, a clear indication can be made of the way in which it must be done.

In this upper-middle management area there are probably fewer activities which will be affected by computer techniques. Nevertheless, a part of the job can be made routine, and, therefore, freed from time-consuming consideration. As a result, there will probably be fewer people in this area; and, as in the case of their subordinate associates, the work which remains will require an even higher level of executive talent than is now required. New attitudes, trainings, and techniques must be acquired for men to adapt to and, as a matter of fact, to guide the automated data processing which supports middle management.

Top management, too, will be affected—but not in the form of having its decision-making made much easier. This level must still operate much as it does today, with a high degree of intelligence, skill, foresight, and courage. The effect will be most felt in the rather pleasant sensation resulting from managing such an effective and profitable organization.

Who is going to effect all this? Someone must be the ramrod to make these changes take place. It will be a man (or a group of men) coming from almost any part of the business. He must be one who understands the industry and his own company and is well acquainted with their ramifications. This implies that he must be one who has had considerable experience within both the industry and the company. He must be one who has a concept, a philosophy of computer use, one who realizes that it is the system, the philosophy, and the concept that will bring about these changes; that it is through the application of the computer as a tool, not as an end in itself, that these changes can be made possible.

But this individual alone cannot do it. He must have recognition and support from top management, for his plans can bog down in a welter of confusion, fear, and chaos unless his authority is well defined and supported to insure the high degree of co-operation that he requires. It is important that there be a large element of faith. This individual's function is new in business organizations. In the internal line of the company, that is, the line that extends from the development of the product through sales to delivery of the finished goods, he must be associated with those who establish policy, for execution of the policy decisions will fall largely under his control. The area of data processing, which has always existed in one form or another, is being consolidated, centralized, and molded into the organization between and surrounding the historically established departments. The new technique assembles parts which were formerly administered by many different persons, and creates an adhesive that binds the operating divisions into a more rigid homogeneous company whole. With this vast activity under his control, it seems that his stature will probably approach the level of top executives in charge of sales and production or their equivalents.

It is now some four and a half years since we began our study and some two years since we received the computer, so it is a good time to examine both our progress and the route ahead. Despite all the discussion which has taken place and the literature which has been written about the difficulties of installing a computer, nothing but the experience itself can bring home the actual difficulties. Details must be analyzed, scrutinized, and policed as never before. A language develops concerning the computer and the systems, with terminologies completely foreign to the business to which they are being applied. There are times when one wonders how far afield one can go in the computer application and still be within the scope of the business whose processes are being affected by the computer.

By centralizing data processing and applying electronic techniques, one creates conditions in which a minor correction, which could formerly have been handled by nearly anyone, becomes a major undertaking; and one discovers that it sometimes requires the collective effort of nearly the entire staff to determine what course of action must be taken to meet some unusual condition. While we have had perhaps a minimum of this kind of experience, there have been enough blunders in the introduction of material to the system to make us shudder at what would have resulted had we been less careful in developing our system and writing our programs. Change does not become easier as integration proceeds. Instead, it becomes more difficult as more and more computer runs become involved.

Despite the advances in so-called automatic programing techniques, this is probably one of the most fertile areas for improvement. Programing is a most burdensome chore, and again it becomes progressively worse. It seems to us that the equipment companies have developed machines which are far more advanced in their capabilities than are the techniques for using them. Sometimes it seems that it would be best to call a moratorium on additional equipment development, so that people attempting to use the machines can bring out the full potential of already existing equipment. This, of course, cannot be done, but it is a happy thought.

Our computer is presently being used sixty hours a week, fifty of which are spent on production and ten on testing for future applications. Our plan calls for the eventual use of three shifts around the clock.

We have progressed about twenty-five or thirty per cent of the way into the first phase of our long-range program. As we advance into each additional area, new applications on the perimeter suggest themselves. Therefore, we see no immediate end to the expansion of integrated and automated data-processing systems. In fact, applications omitted from our first phase are now being examined for the possible use of an additional electronic computer. We must conclude from this that there are probably twenty more years of work before a plateau is reached and the full impact of an automated data-processing system will be felt.

We are pleased by the system's performance. The technical results that we anticipated have been achieved in each segment now on the computer, and the costs are remarkably close to those that were estimated in our original survey. In only one area have we made a mistake of consequence, and this was in the evaluation of development and programing. Although we almost doubled the manufacturer's recommendations in programing hands, we would, if called upon make this decision again, double the number of hands to reduce the time required for the arduous programing job.

Our performance has been better in producing reports than it has been in the application of this new information by the people who receive it. Results from better statistics have been far short of the full potential, because of a lack of intelligent human action. This very fact is one of the influences stimulating toward more extensive automation. We have come to be more perfectionist in outlook than ever before and, as a result, are less patient with human failures on work which could be done with more speed and accuracy by the computer. Until more extensive automation is accomplished, more education of personnel is indicated.

Not everyone is so enthusiastic about the computer as the persons who are closely connected with it and its installation; but the feeling of satisfaction (not complacent satisfaction) is spreading to others as they see results in the activities under their control. No one can be unimpressed by the reduction of our finished goods inventory from a peak of 11,500,000 pairs at the close of our fiscal year of 1954 to 8,000,000 pairs on November 30, 1958—and this done simultaneously with providing the best service in the past five years to our customers.

Not all of this can be attributed to the computer and the program it represents. A great share must be credited to the change in organizational structure, and also to the sheer will to reduce the inventory; but it can fairly be said that neither the organizational changes nor the pressure to reduce inventory could have been so effective if a better reporting system had not pointed out where these reductions could be made.

Impressive results are evident from production planning. In one factory selected as a testing ground, the days in process declined from 15.8 to 5.7, and the number of schedules wholly or partly in process declined from twenty-three to six.

Similar results have been experienced in computing requirements of raw material in one hour and fifteen minutes daily, as opposed to three to four days when done manually. Preparation of estimates of raw material is now done weekly in less than one-half day, whereas it formerly took three weeks. The context is even more impressive than the timing. The old estimates covered total quantities of upper leather only, whereas the new estimates include the factor of timing as well as quantities, and now include all of some 15,000 shoemaking materials.

Our balance sheet and our profit and loss statement are being watched closely. The development period has been quite expensive; but we are now reaching the point of payoff. We are seeing evidence that the trends are in the right direction. It appears to us at this time that continued success in applying the techniques of our program will not only recover what we have put into it over the past five years, but will dramatically increase our profits in this competitive business.

Those closely associated with the machine feel that the new concepts which have developed, in conjunction with the application of electronic computers and the automation which follows, create an extremely sharp competitive weapon and that, while the cost of implementing this sort of program is great, the cost of not doing so can be even greater. In the long run, it could mean the difference between being in business and not being there.

[*Comments made at the Seminar by Mr. Vogt as a supplement to his paper*]

We are beginning to see the real impact of information technology at International Shoe Company in the form of radical changes in the accepted balance sheet ratios by which the company historically has operated. Information technology is beginning to shake up the established norms—the traditional yardsticks—by which we measured our own performance. These changes are coming about because we (1) have better control of our business, and (2) we have a greater knowledge of our business.

Our experience has been highlighted by what has happened to our inventories. We have a very high-style type of business with a product that changes every six months. At the same time, we have a tremendous variation in styles during any given season and a very large run of shoe sizes. The constant change means that twice a year we retool, change layouts, and make substantial alterations in our material stocks. The variety is illustrated by the fact that one stock number which pertains to a particular style, color, and material of shoe will then have anywhere from 99 to 125 variations in size. We thus have a tremendous problem of data introduction.

In my paper I referred to a reduction in finished goods inventory from 11½ million pairs of shoes in 1954 to 8 million pairs in 1958. This reduction is very important to our company. First, we have fewer dollars tied up in inventory. Second, since our product is a perishable one, we have been able to make great savings in avioding markdowns which result from having the wrong shoe at the wrong time. Our ratio of inventory to sales is now the best that it has been in the past ten years. It is this ten-year period which really marks modern shoemaking technology. These savings, added together, mean that our ratio of current assets to total assets is at a far more desirable level than it has been during recent years. It means also that our company's cash position has greatly improved.

Not only have our major ratios changed rather radically; some other changes have occurred. A major change is that many decisions formerly based upon the judgment of people at the middle level of management are being reduced, not to decisions within a computer, but to simple recognition of an existing condition. If we think of the flow of information within the typical organization as a triangular shaped affair with a broad base of facts moving upward to some point at which management reduces these facts by interpolation into decisions, then the effect of information technology is to move the level of facts higher in this triangle. Where formerly people had made decisions "by the seat of their pants," by interpolating facts and using judgment, we now need to do so less and less. It is possible that this interpolation can be reduced to the point where no decision is left—where the facts simply state the existing condition and indicate action. In business management, we are moving away from an era of decisions made by intuition into an era of decisions made on the basis of facts. This is analogous to the changes in the last several decades in the way pilots fly airplanes.

A third major effect of the new information technology is that large businesses are becoming more manageable by being made more like small businesses in their operations. The computer becomes a sort of binding agent, bringing departments closer together, poking holes in departmental walls, and, in fact, causing departmental walls to "come tumbling down." Information technology has the effect of breaking up self-contained dynasties within the organization. The results are to move the business toward the situation that exists in the small company whose manager has all the various functional aspects of his business in his mind and within his own mind can correlate one function with another. Large businesses have great difficulty doing this simply because of their size. Information technology, by increasing the flow of necessary information among departments, makes for better coordination and helps restore some of the flexibility that is characteristic of the small business.

At International Shoe we believe that information technology is not a staff function, but a line function. This is an important point. We believe that a man or men in charge of this function cannot be placed off to the side somewhere in a staff capacity, but must be directly involved in all aspects of the business from product development through sales. I can illustrate this belief best by giving you some description of the program we have set up at International Shoe Company.

The company embarked on its information technology program at a time when it was facing a serious business situation. We saw the program as a possible means of bailing the company out and therefore operated at forced draft. This is the source of my belief that it is important to "ramrod" the program through, especially under these conditions. Our faith in information technology stems from our basic belief that the source of our difficulties was a lack of co-ordination and understanding in interchange of information between different groups and divisions within the company.

Our program starts with a very high-level general sales estimate, from which related production estimates are derived. Then this information filters down to a group of people called merchandise men, who try to translate the wants and desires of the sales people into the capacities of the production people in terms of crude, but specific, sales estimates by stock numbers. These estimates, made by merchandise men on the basis of past records and intuition, are then introduced into the computer and compared with factory capacities and capabilities. This gives us a rough production plan.

When we chart the desires of the merchandise men, we get a rather wildly fluctuating sales curve which reflects the high seasonality of our product. While we have a widely fluctuating sales curve, our factories operate most efficiently if they are run on the basis of steady production. Through the computer, which uses a highly sophisticated program, we in effect push the peak of our sales curve back into the previous trough for production purposes. In other words, we manufacture in anticipation of sales. The program for filling this trough is based upon a classification of shoes according to the stability of the style from season to season. The program first feeds back into the trough the most stable group of shoes. If this does not fill production capacity, then successively more hazardous and risky styles are filled in until a condition approaching capacity is attained. This program takes into account also the various time cycles involved in material processing and production.

This sort of planning is done weekly and a balance is achieved. Balance can be achieved because all the different parts of the picture are flexible—the sales estimates, the factory capacities, the timing of deliveries, etc. In other words, not all adjustments are made in terms of sales and deliveries. Where economically feasible, factory capacities can also be adjusted.

Our program then explodes stock numbers into component parts and then into material needs by quality of materials, quantity of materials, and timing requirements. The magnitude of this task is indicated by the fact that it involves around 12,000 stock numbers and about 16,000 types of materials (bought by thirty-seven buyers and distributed to 250 factories). This materials explosion is then sent to the purchasing department.

With our program we can, through explosion, get estimates of operating needs, labor needs, and needs for machinery and equipment. In this more detailed explosion we sometimes find it necessary to change our estimate of production capacity, since the refined calculations will reveal bottlenecks that were not apparent when we were dealing with estimates using grosser categories. For example, we may discover a manpower shortage which simply cannot be filled by training within the necessary time, which may indicate that a certain type of shoe cannot be produced in the quantity wanted or within the time specified. New information developed from these explosions can then be fed back into our system and another balancing-out process takes place within the computer.

For years, one of our troubles had been that we had never been able to recognize trouble until it was right on top of us. Now, with this constant recalculation of sales against materials and against production capacity, we can see the trouble coming in time to take steps to avoid it.

We can foresee the day when the merchandising man's job will be further programed. The records of sales and stock controls can be fed back into the system and used to recalculate sales estimates and production needs. The merchandise man has always had to operate by hunches; but we believe, particularly when the averages can be kept right up to the minute, that these averages will be better than hunches and will lead to further programing of shoe buying. This will be possible chiefly because we have developed a highly integrated information system.

A by-product of our improved scheduling and greater coordination between production schedules, materials ordering, and scheduling of labor has been a reduction of the amount of time that goods are in process in our factories. In one factory this average time was reduced from 15.8 to 5.7 days. This reduction in time has in turn had a number of by-products. One is that the quality of shoes improves: shoes dry out less in process and are less subject to other forms of damage. Fewer operators are earning more money, so that our direct labor costs are down while the operator's earnings are up. Furthermore, with a steadier flow of shoes, the cost of factory overhead per pair comes down.

In the area of materials ordering, many decisions which were formerly based on judgments have been reduced to a routine. Records are developed which clearly indicate the action that should be taken and thus replace decision-making by the "seat of the pants" method. The superiority of this method was dramatically illustrated in a recent failure in our set-up. A large volume of shoes were waiting for buckles. The material needs had been analyzed correctly and the order had been placed with a supplier who was usually very reliable. In this particular case, however, he did not deliver the materials on time. Despite warnings from the factory, the purchasing people did not take follow-up action and, when they did, they did not transmit any sense of urgency to the supplier. As a result, the buckles were sent out by rail rather than by plane. If we had had some automatic follow-up by the computer, we certainly would have avoided some of this trouble.

In summary: through our system of estimates and information processing we have achieved a state in which production, merchandising, and procurement no longer function as semi-independent entities. The information system has tied these units together so that, functionally, they are now one unit, since the planning and estimating system that we use is so pervasive and has behind it such full administrative control that we believe it unrealistic to conceive of it as a staff function. Information technologists who build information systems of this sort are, in large measure, clearly indicating the decisions which other individuals in all departments must make.

A DEPARTMENT OF THE GENERAL ELECTRIC COMPANY

By

John E. Hines[*]

[*A summary of comments made by Mr. Hines at the Seminar*]

THE SYSTEM WE USE at the Distribution Transformer Department of the General Electric Company is so much like the one described by Leonard Vogt that I will simply make a number of points, more or less at random, to fill in some gaps in his comments.

First, our experience indicates that not only is it important to talk about the ways information technology affects the organization, but also about the ways the organization affects and sometimes impedes the development of information technology. We have been too preoccupied with organizational charts and with the establishment of similar jobs in each division and plant. This sort of preoccupation impedes the development of an effective information system, since people do vary a great deal, and the nucleus for effective development of a system, the outstanding man, may be held back.

A further disadvantage of being preoccupied with organization charts is that it becomes difficult to cut across departmental lines in developing the kind of system which ties together different departments and divisions. For example, I am located in the production area. The systems that my group has been developing reach out and deal with marketing, financial information, costing, and, in fact, the general management problems of the entire business. Information technology must embrace the total business, since it integrates both planning and execution in a general way.

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[*] Supervisor, Production Systems, Distribution Transformer Department, General Electric Company.

This integration can be illustrated by some examples from our own operation. Engineering of transformers is a "cookbook" proposition and can be put right into a computer. Thus we can readily evaluate various ways of designing the product. In our case, this has already resulted in some product redesign. Another example relates to the cost system: in our parts explosion we can cost the entire operation in a matter of eighteen hours. The implication of this is that we can avoid the annual computation of standard costs with subsequent operations based on variations from standard, and move toward the use of actual costs computed once a month. Further illustration of the integrating effects of such systems is provided by the fact that a new operations research man employed in the marketing division of this department finds that about ninety per cent of his job has already been built into the data-processing systems set up in the production area. Therefore, from an organizational point of view, I want to reassert the point, made earlier in this Seminar, that work on information technology should proceed from a central location in the organization.

It seems to me, as a matter of fact, that a very useful principle I learned while chasing rum runners for the Coast Guard can be used profitably in developing information technology. This is the principle of "hot pursuit." You may not go off limits to find a smuggler but, once on his trail, you may pursue him anywhere. In our organization we have adopted this principle. When we find a problem we pursue it wherever it may lead in the organization and, as a consequence, have in fact got into almost everything in the business, although we started in the production area.

In setting up our information technology system, we have run into some difficulties which may be of interest to other people contemplating such an activity. One of our problems has been the very long time that it takes to get changes accepted. In our experience, it may take as much as three or four years to bring the organization around to accepting a system already developed. Vogt pointed out that the facts in many cases indicate action. We have found that we sometimes must deliberately build human decision back into the system, even though it would be possible to run without it. We must do this in order to gain acceptance for the system. For example, we have occasionally tacked on a piece of hardware simply to gain acceptance. The device we have found useful is some sort of random access equipment such as the RAMAC. When people can retrieve information from the system any time they want it, they feel they have it under control to a greater degree and therefore are more willing to accept it.

Another point we have learned is that knowledge of the jobs involved is indispensable in developing an information system. People with this knowledge sometimes can build a system which is much simpler than one mathematicians might put together.

I am very much worried about our personnel problem in this field. We are under organizational pressure to give the programs we develop "back to the factory" once we have designed them. But in many cases the factory people do not understand them well enough to operate them successfully. To train a man properly in this area, direct involvement in development of the program is important. It is very difficult to write up a program and expect people to understand it by reading about it.

Another aspect of our personnel problem is the lack of promotion opportunities for the man we train in our section. We have not yet, in our organization, figured out the lines of career movement for these people. This we must do, and will do, but only after some breaking down of traditional departments has occurred.

DISCUSSION

[*Discussion of Comments by Mr. Vogt and Mr. Hines*]

Rush: I am disturbed by Vogt's emphasis in his system upon increasing the speed in precision measurement of things like seasonality of sales. Aren't we running the danger of accepting traditional ways of looking at things as "givens"? Doesn't this "actuarial" kind of approach divert attention from important problems, such as trying to eliminate or mitigate seasonality instead of accepting it?

Vogt: I agree that it would be a mistake to overlook the possibility of eliminating seasonality as an important problem. I feel, however, that your reactions grow out of my emphasis on only one area of our operations. This is the area of adapting production patterns to the existing sales patterns for optimum operation. We have chosen to emphasize finished shoes. That is, we emphasize the pattern of movement into the market of finished shoes rather than, say, the movement of raw materials, because we believe that the optimum movement of the finished article has much more important financial implications than some optimum handling of raw material ordering.

Now, we are in the process of looking more closely at sales data by trying to pick up our data at an earlier stage. We are trying to get data on daily sales across the retailers' counters. At present, our data are based upon retailers' orders. In the recent recession, when retailers' orders fell way off, the company was caught off base because what was happening was not really a decline in shoe sales but a decline in retailers' inventories.

SIMON: The essence of these information systems is not their accuracy. The important thing is that data are now put together in such a way that a man can assess the implications of any occurrence or any decision for various parts of the business using the same data. The aim in adopting these new systems of information analysis is to take care of the future intelligently without incurring unnecessary risks. An important part of the systems is the continual feedback of information from the environment to decision points. This permits rapid adjustment to new conditions, whether the new conditions are externally caused or reflect changes in internal operations. Speed of recirculation of information in a system such as Vogt described is of the essence. Accuracy of the information is of secondary importance.

VOGT: Simon is correct. We are already setting up plans to use today's sales to draw up tomorrow's production schedules. This would mean that the present weekly cycle will be reduced to a daily cycle.

(*Editors' interpolation: It appears from Vogt's discussion and Simon's comments that an important dimension of information technology is the ability to collapse the planning period which has been traditionally accepted in business as inevitable. By being able to process a large amount of data about rapidly occurring changes in the environment and to process it very quickly, the lapse in time between the occurrence of events and the adjustments in the firm's behavior becomes very small. The process of constant adjustment and balancing out described by Vogt in effect reduces the need to peer far into the future. If the business can readjust estimates very quickly and very frequently, no single estimate needs to speculate very far on the future course of events. This shows up, of course, in lower inventories and in greater flexibility of movement in adapting to surprises.*)

GROSZ: I would like to make a couple of comments on Vogt's presentation. First, I agree with the idea that these developments must be "ramrodded" through. They are too big and pervasive to be established any other way. Second, it is my understanding that the chief contribution of information technology is to permit the co-ordination of many variables which are impossible to use in a system operated exclusively by human beings. Our pre-computer method of planning necessarily involved approximations. In these approximations we treated as unimportant many variables which are really quite important.

Orden: Is this ability to get many facts very rapidly of any economic significance? Couldn't some sampling or mathematical-model approach do just as well?

Vogt: We have not become so sophisticated as yet that we have tried to use mathematical models. Our efforts remind me of the series of developments of gunsights on anti-aircraft guns. Information about the preceding burst of gunfire is fed back in order to correct the aim for the subsequent shot. With a fast enough feedback and correction system, the shots become more rapid and closer to the target all the time. This, in effect, is what we are doing with our system. The major contribution of our information technology system is that it permits rapid translation of plans into the language of operating personnel and feeds this information out to all the people affected.

Hunter: It is possible to get the same effect, to some degree at least, by staff meetings in which individual personnel affected attend the planning sessions, hear of the plans, and raise questions about how this translates into action for them in their own departments.

Simon: Actually, if you understand your business well enough, and know all its major parameters or dimensions, it is possible to incorporate this information into some sort of mathematical model. But even when this is done it is only a very general and high-level set of plans which still leaves unanswered the specific courses of action for the operating level. Given the fact that you want to maintain certain inventory levels, for example—what does this mean to the individual plant supervisor in terms of how he schedules production for the day and how he handles his stores of materials for the coming week? It is possible to set up these aggregate models without the aid of a computer, but the computer really functions best as a coupling to bring these over-all plans down to operating-level programs of action.

ALBERTS: I think it is wrong to imply that the communication network is the same thing as the organization structure itself. I think that Vogt is really talking about a greatly improved communication system which eliminates the biases and distortions in information resulting from variations between individual or small-group goals and the goals of the organization as a whole, and also from the time lags. No matter how you clean up the information you still can't close the loop in the sense of eliminating, at least at the upper levels, the intervention of people exercising judgment.

VOGT: I agree with you, but I think we should also reckon with the fact that organization is being affected. Today we have a vice president of *merchandising and production,* whereas up until recently these had been separate functions. Our new information system has pointed up the very close relationship of these two functions.

SHULTZ: What has happened to the job of the factory manager in International Shoe Company? How has this new information system affected what he does?

VOGT: The factory manager is quite enthusiastic about the new system. He feels that it has enhanced the dignity of his job. It has changed him from an expediter, rushing around trying to put out fires, and has, because of the smoother planning, allowed him to concentrate on his real problem of costs and quality within the factory. With the foreman level, however, reaction is not quite so positive. The foreman isn't too sure of what precisely has happened. But he finds himself under compulsion to follow a precise schedule, even though he might prefer to do things in a somewhat different way.

UNITED AIR LINES

By

Warren E. Alberts[*]

One of the first impacts that "information technology" has on a company is bringing about the sudden realization that many of the functions which must be integrated to do even a fair systems analysis job are organizationally spread throughout the company. There then follow attempts to form "task forces," co-ordinating committees, computer feasibility study groups, and so on. Too often these groups do not recognize the full implication of such a study. They become hardware oriented and lose sight of the need first to analyze and determine the company's basic information needs.

United Air Lines was fortunate in that its president, Mr. Patterson, back in 1940, recognized the need for a department which would look at the company's needs as a whole and continually search for better ways of doing things.

As a result, we have today what we call our Industrial Engineering Department, which includes such functions as organization planning, work analysis, quality control, operations research, data processing, and regulations and forms (see Exhibit I). This is organizational recognition of the need to integrate those staff functions which are required to analyze and design new information and management systems, along with the new management techniques or tools which the operating managers and staffs need to

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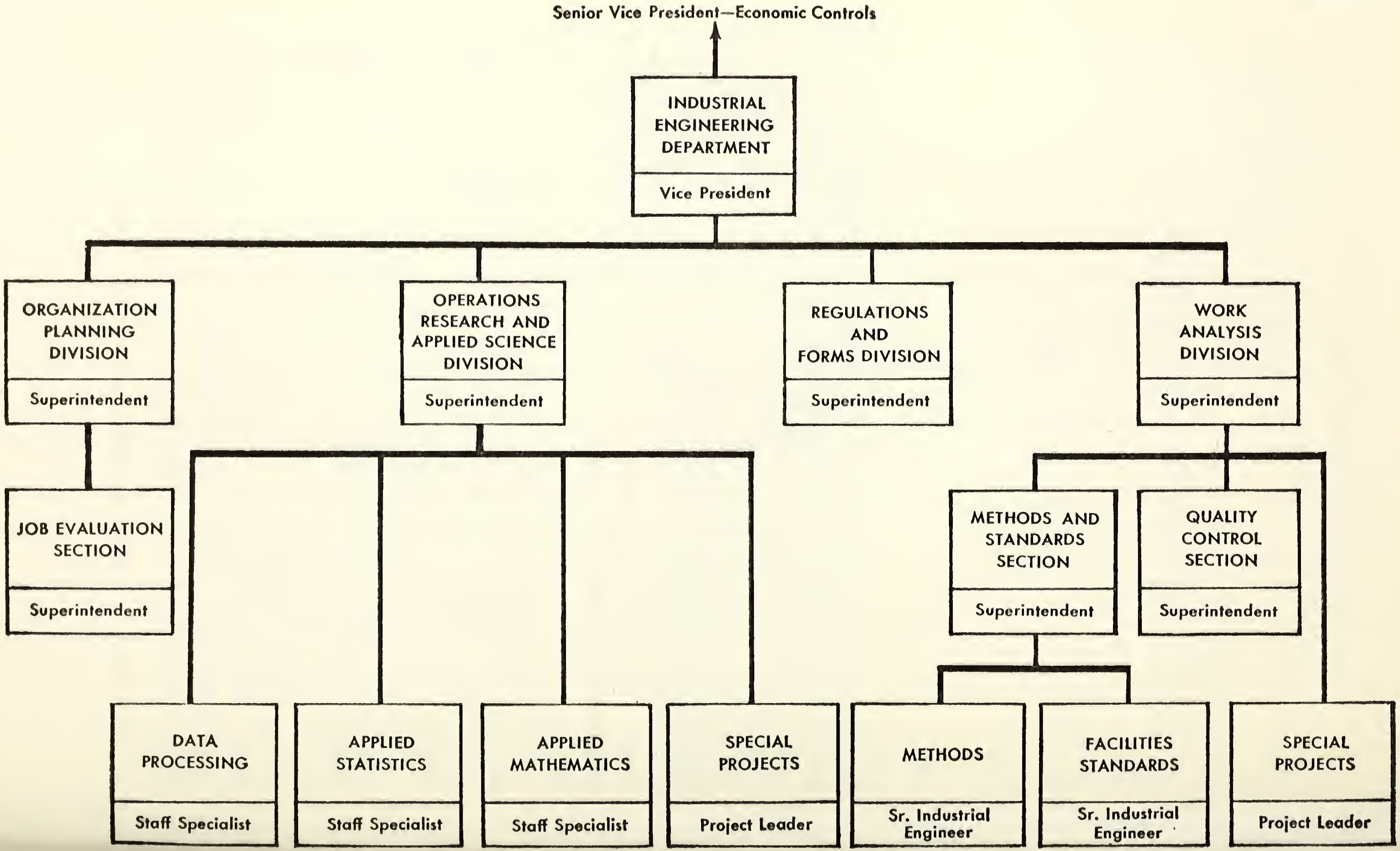
[*] Vice President, Assistant to the President, United Air Lines.

EXHIBIT 1


Senior Vice President—Economic Controls
INDUSTRIAL ENGINEERING DEPARTMENT
Vice President
ORGANIZATION PLANNING DIVISION
Superintendent
OPERATIONS RESEARCH AND APPLIED SCIENCE DIVISION
Superintendent
REGULATIONS AND FORMS DIVISION
Superintendent
WORK ANALYSIS DIVISION
Superintendent
JOB EVALUATION SECTION
Superintendent
METHODS AND STANDARDS SECTION
Superintendent
QUALITY CONTROL SECTION
Superintendent
DATA PROCESSING
Staff Specialist
APPLIED STATISTICS
Staff Specialist
APPLIED MATHEMATICS
Staff Specialist
SPECIAL PROJECTS
Project Leader
METHODS
Sr. Industrial Engineer
FACILITIES STANDARDS
Sr. Industrial Engineer
SPECIAL PROJECTS
Project Leader

get the job done. One might think of this whole effort as an attempt to invest, for maximum return, innovative effort on the management and human side to balance the research and development effort on the physical or product side.

INFORMATION REQUIREMENTS

Since we have the responsibility within the company for sparking, evaluating, and applying new computer and data-processing systems to the company's advantage, from the start we have viewed with concern the tendency in industry to take a computer when it is put on the market and look for an application, instead of first analyzing the problems inherent in operating and information systems and determining just what are their needs and requirements. The latter approach often leads to solutions which have nothing to do with computers, but which may involve new techniques. This happened in our application of sampling to the settling of accounts between airlines.

In 1954 we undertook a major study of one of our key problems in the company, that of routing and maintaining our aircraft over the entire system. In taking a close look at our operation and in trying to measure it and understand the facts of life, we discovered that much of the information we needed to answer basic questions concerning our operation was not available. It appears to us—and I think it is generally true in industry—that much of today's information is designed to satisfy governmental, legal, and accounting requirements, with little recognition of what the various levels of management need as a base for the types of decisions which they are called on to make.

This work also brought home to us the fact that few information systems recognize the importance of variation. Today's accounting and other measurement systems seem content to deal in averages. There are many procedures, policies, and kinds of equipment all set up to take care of the rare chance of occurrence with no real evaluation of the risks involved. It is important to recognize the probability of things happening, because it is only through knowing the variation in an operation that one really has the clue to understanding it, improving it, or recognizing the interaction which takes place.

We must first determine what information needs to flow and its relative value. Within the company we are taking the approach that, on any systems study, our first task is to establish what elements in the system are measurable, variable, and controllable, and then to determine the economic value to the company of getting information about these elements.

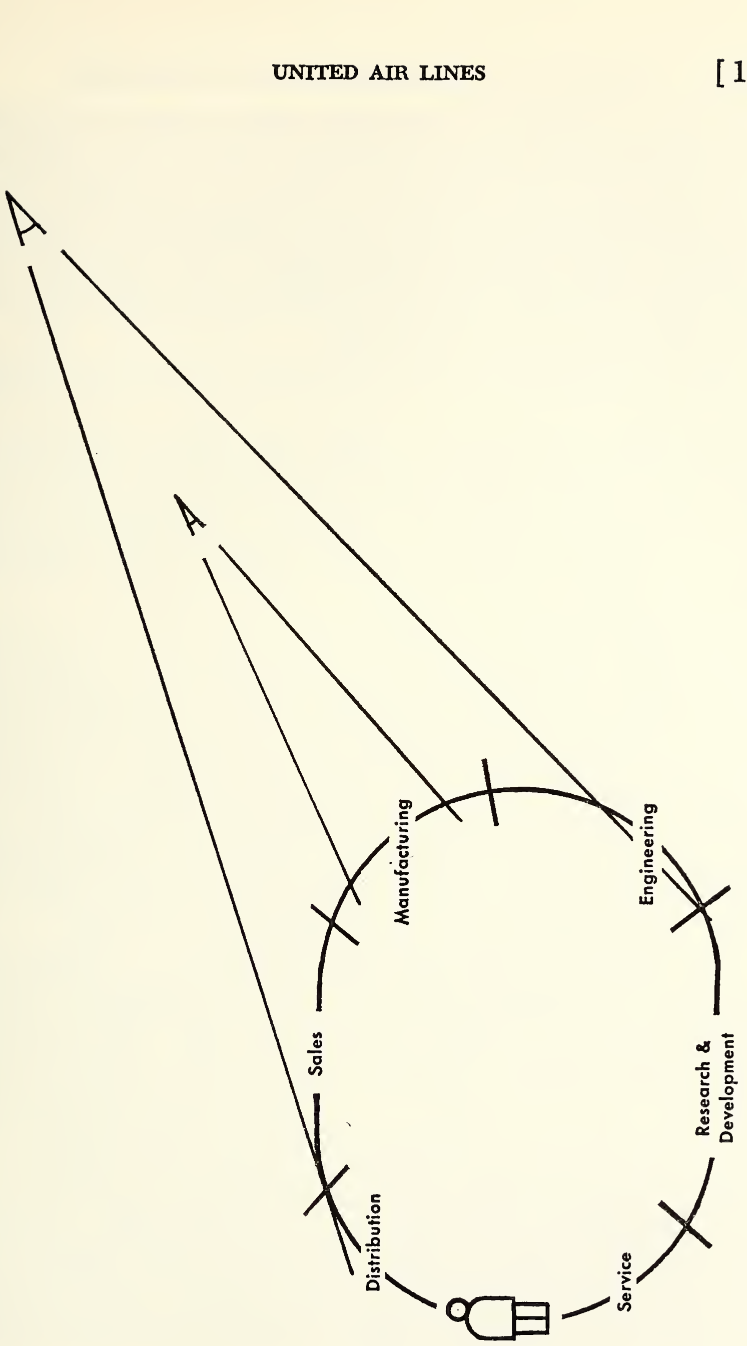
A critical area in designing a general management information system is the development of ways to portray information that will excite people to action, not deaden human response. We have observed that one of the effects of integrating systems is to "depersonalize" information. If a problem becomes apparent to all at the same time, as it does in an integrated information system, no one person or department needs to bear bad news or to point a finger at another. Considering that one of the hardest things to do in any group is to expose a problem without provoking human defenses to becloud the issue, this is an effect of significant impact.

When new tools of measurement are being designed, it is usually of little use to ask a manager what information he needs to make better decisions. In most cases he is not aware of what information tools can be made available to him. He does know, however, the types of problems and situations with which he is confronted and the basis on which he presently makes decisions.

Our work to date has led us to believe that a basic change in the type of information desired is coming. This can best be illustrated by a change in the question to information sources—*from* "What's the score?" and "How have we been doing?" *to* "How well are we doing in comparison with the best we could be doing?" and "If we continue on the present course, where will we be?" or "If I change this equipment or concept in my system, what are the likely consequences?"

IMPACT OF SYSTEM ANALYSIS

There is no question but that the computer glamorized, for the first time, the attack on paper work procedures and information


A
A
Manufacturing
Engineering
Sales
Research & Development
Distribution
Service

flow which had heretofore been sadly neglected. However, it would be a mistake not to recognize that the computer and associated technology will makes its greatest contribution not through a direct attempt of application as such, but by stimulating the analysis of systems by which companies are operated. This, for many companies, means breaking down traditional organization curtains and a no-holds-barred pursuit of problems.

This over-all approach can be illustrated by the picture on page 165, with the eye closest to a particular function, showing the fire fighting and partial analysis so often done today because of the organization location and specialization of methods and procedural groups. Since the solution of problems in one area almost always affects the system of which it may be a part, we find it essential also to consider the system from the total viewpoint, as illustrated by the second eye.

When this kind of approach is taken, the need to integrate staff specialties and viewpoints is apparent. It is no wonder that many managements today are confused by the tremendous number of staff specialties which they find spread throughout their organization. For example, if one is really going to take a systems approach to a problem, there can be involved such titles and individuals as methods engineers, tool engineers, data-processing specialists, programers, quality control analysts, time study technicians, psychologists, organization planners, and so on.

The problem of integrating these specialists is a difficult one; and herein, we feel, lies the role of the industrial engineer or someone who utilizes the industrial engineer approach. After all, we are talking about an engineering task which involves analysis, design, application, and development. Unlike most engineers, the industrial engineer's work revolves around human beings and the highest use of their productive resources. Some people still think of the industrial engineer as the time study or efficiency expert of twenty years ago. Many managements, however, are becoming aware that industrial engineers have made tremendous strides in their organized approach to problem solving and systems analysis in larger industry problems, and that they are already assuming their role of truly being *engineers* to *industry*.

To illustrate the role their professional society has carved out in this field, I quote the official definition of industrial engineering as published by the American Institute of Industrial Engineers.

> INDUSTRIAL ENGINEERING is concerned with the design, improvement and installation of integrated systems of men, materials and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems.*

Regardless of what one calls it, the successful design of company systems necessitates that the primary company functions involving establishment of the job to be done, the organization of people to do it, the design of tools to measure and operate it, and the effort to analyze and improve it should all be under one head. As can be seen in our own organization, we have integrated these staff functions at a high level within the company, yet promoted the development of technical and specialized staff specialties in departments wherever they could be most effective.

One of the positive reactions to the systems approach is that people at various levels of supervision are able to recognize, in many cases for the first time, their roles in the company. Also, seeing themselves as part of a system helps them mentally to integrate the specialized staff techniques which often seem overly sophisticated, complex, and conflicting. The systems approach has also awakened us to the need for developing general practitioners in our field—men who are trained in the diagnosis of an industrial system's ills and have sufficient knowledge to consult whatever staff specialists or technicians are required to define the problem or develop practical solutions.

This points up the acute need today for translation—by this I mean the need for a communication link between the management scientist or mathematician, if you will, and management; or, in the information field, between the computer manufacturer and the businessman with an information problem. It appears that there are many people today who are ignoring this age-old necessity. In illustrating this need for translation, the following links come to mind:

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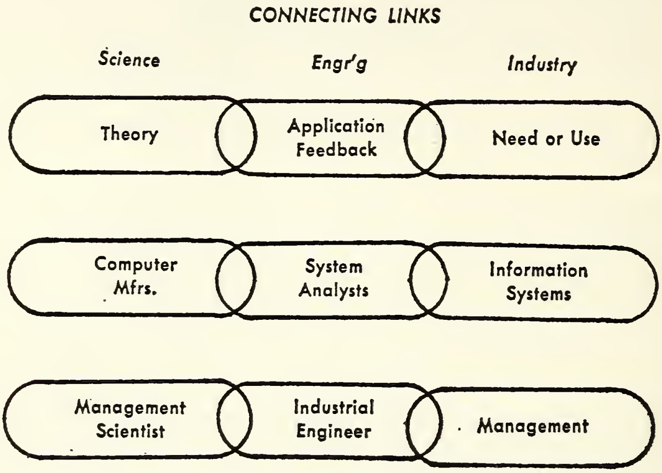
* Austin Weston, "Summary of The Industrial Engineering Symposium, Cornell University, October 1955," *The Journal of Industrial Engineering,* Vol. VII, No. 3, May–June 1956, p. 98.


CONNECTING LINKS
Science
Engr'g
Industry
Theory
Application Feedback
Need or Use
Computer Mfrs.
System Analysts
Information Systems
Management Scientist
Industrial Engineer
Management

When the connecting link is left out, the result too often is that of groups speaking entirely different languages; of techniques and technology looking for problems rather than the problems setting forth the need for new technology.

THE COMPUTER'S ROLE

If one thinks of the computer as an extension of our mental skills, as the machine was of our physical skills, a better perspective on its ultimate use will result. Our definition of activities such as decision-making, planning, supervision, and creativity will be more affected by projections of the computer's assuming human or managerial roles than will the human role in management.

One has only to observe the way present-day managers spend their time (as derived from work sampling studies) to see that the computer and associated data-processing systems are primarily going to free him to do that part of the job which only he can do. This simply means that the clerical and information-gathering and dissemination activities of most jobs today prevent managers from getting to the big print in their job specifications.

The computer is basically a processor of information and, as such, can be expected to take over those information-processing functions where its speed and capacity can be made to pay off without sacrificing flexibility. Its ability to reduce the costly time lags and fill the voids in present-day communication systems will gradually revise our ideas about what is necessary to plan and control an operation. As system analysis identifies information systems and the computer makes possible their integration within the company, we feel that the organizational structure will change from the traditional sales, manufacturing, etc., functions to one that reflects, for example, the distribution, planning, material handling, and servicing systems which today crisscross all department lines.

Real Time Information Systems

Our experience to date has convinced us that the most profitable application of the computer and associated communications networks will be in performing a part of the operation rather than in keeping score or in substituting for bits of paper. We are discussing the use of electronic equipment as real time devices; in other words, their function must be performed at a given moment and as part of the process.

This was dramatically demonstrated to us in the development of our electronic reservations system. Our approach to the development of this system exemplifies some of the things we have been talking about, and it might be well to describe briefly some of the history here.

In 1955 the company decided that our reservations function —which employed over 2,000 people, cost us some $12,000,000 a year, and handled up to 50,000 trasnsactions a day—needed a thorough systems study. We established a team of men headed by an industrial engineer and gave them the following assignment: analyze the entire system, isolate the basic problems, measure the key variables, and project the system and its requirements ten to fifteen years into the future. In order to prevent gadgeteering, we set the development of a use or functional specification as the goal of this team.

This took almost a year to develop and we soon found out that none of the manufacturers could meet it, nor did any have a real appreciation of such an over-all approach to information systems. Since we felt sure that the objectives could be met, we asked Stanford Research Institute to take our functional specifications and see whether there existed, in this country or abroad, the technical know-how or ability to put together a system which would meet our requirements. We also pointed out our feeling that many manufacturers were unaware of the queueing problem, which needed attention in any system which could meet our requirements for response times and still be economically feasible. Stanford Research Institute evaluated the state of the art here and abroad and developed a plan for utilizing available equipment to meet our needs.

As a result of this work, we became aware of the possibility of using computers as organizational blocks and assigning different functions and task levels to them. For example, where speed was not a primary factor, limited intelligence and memory tasks could be assigned to that computer segment. We found, however, in trying to meet what now amounted to technical specifications, that the manufacturers could not guarantee our operating specifications with existing equipment. It was only after the field had been whittled down and the broad scope of this project finally realized that we were able to get a system that would do the job.

Basically, the system will consist of two transistorized computers in Denver linked with miniature computer switching centers in our key cities—they in turn serve over 700 agent sets throughout our system. The Teleregister Corporation, which will provide the computers and the input and output devices or agent sets, had to go outside the country to obtain the computer-type switching centers which actually proved to be a key factor in the whole system.

While we were working on this system, which will be installed and operating in 1960 and will take care of our needs through 1970 and beyond, we were also busy making interim improvements on our reservations system. These interim improvements, which were largely in the communications and data-processing fields, included the installation of two IBM RAMACs (Random Access Memory file And Computer unit) at our central Space Control Center in Denver and the use of transceiver links to our key offices, which had been utilizing IBM equipment, Teleregister availability boards, and agent sets for some years.

It is interesting to note that in trying to solve a service problem, we found a new system that would not only amortize itself, but make a real contribution to profit. This leads us to believe that there exists in industry today some real chance for increase in productivity by the introduction of over-all systems such as this.

An important discovery resulting from our work in this area is the knowledge that our data-processing communications system, although basically designed to serve our reservations function, has the flexibility and capability to expand to assume other information transmission tasks. However, the flow of traffic, on a data-processing system that is used both for transmission and real time purposes, directly affects the queues and response times; therefore, it is important that control of its maintenance, performance, and use be centralized in one function. So here again we see the impact on organization—even before we had the system, we had to centralize the responsibility for the technical performance and maintenance of the data-processing communications network in our communications department.

During the course of this work, it became apparent that there was quite a bit of confusion about just what was involved in the tasks associated with a computer or an information processing system. We had to go to some lengths to explain the differences between the talents, responsibilities, and functions of a systems engineer, a programer, a coder, and a communications specialist.

Again we ran into the problem of translation. We found that we had to sketch out our own organization and functions in order to clarify for other managers just what was involved. Many of the specialty titles have come from areas which are foreign to management, yet the functions which those people perform are rather common in industry. We pointed out that the job of programing was not a technical one requiring an electronic engineering background, but was simply one for a procedures analyst, writing procedures for a machine system rather than a human system—and that his tools, such as a flow chart, were the same as have been used for years. I am certain that some effort must be made in this field to promote understanding in place of obscurity with an aura of technical sophistication.

Before we leave this subject of real time use of computers, let me reiterate that I am personally convinced that some of the greatest payoffs will be by applications in this area. I am thinking particularly of applications in the distribution and production fields. Actually, it does not take much imagination to see that, if simple input-output devices are put in the hands of workers and tied in directly to supervisory points and to material, scheduling, and technical information centers, along with means to record all the essential parts and variations in the process, some real gains will be made in the paper work battle.

System Simulation

This is a field in which we feel we have done some real pioneering. Since time began, man has made models, facsimiles, or representations of reality. The purpose has been to learn from them, test ideas, and predict the effect of acting in a certain way—in other words, to comprehend his environment. When we talk about system simulation, we are talking about duplicating the essence of either a business, military, or other system in such a way that we can work with it.

To illustrate the system simulation model, I would like to describe briefly a model which we started working on in 1954 and which has been in practical use for the past three years. We call this model our station model, since its purpose is to simulate the maintenance operation at any one of our major stations. These stations, employing some 1,000 mechanics, carry out our preventive maintenance program in the field. The program consists of maintenance checks of various types, some requiring docking an airplane in the hangar for some fourteen hours, others requiring the airplane's being on the ramp less than three hours. The model's job is to help find an optimum combination of such factors as labor, hangar facilities, reserve airplanes, schedule and ground times, and the basic maintenance program.

EXHIBIT II

MODEL OF AN AIRLINE MAINTENANCE FACILITY

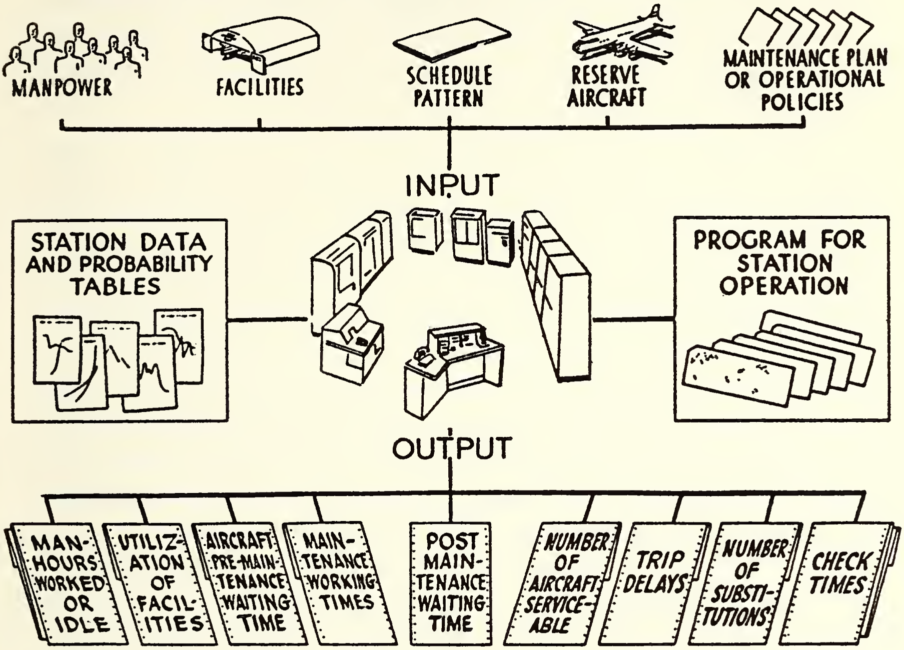

MANPOWER
FACILITIES
SCHEDULE PATTERN
RESERVE AIRCRAFT
MAINTENANCE PLAN OR OPERATIONAL POLICIES
INPUT
STATION DATA AND PROBABILITY TABLES
PROGRAM FOR STATION OPERATION
OUTPUT
MAN-HOURS WORKED OR IDLE
UTILIZATION OF FACILITIES
AIRCRAFT PRE-MAINTENANCE WAITING TIME
MAINTENANCE WORKING TIMES
POST MAINTENANCE WAITING TIME
NUMBER OF AIRCRAFT SERVICEABLE
TRIP DELAYS
NUMBER OF SUBSTITUTIONS
CHECK TIMES

Exhibit *II* is a symbolic representation of the model and its over-all operation. Although we wanted to express the station operation in an analytical form, we could not find anyone who could do so. Therefore, we resorted to a logical step-by-step programing real life at a station.

In simulating the flow of airplanes through a station and the accomplishment of work, it was necessary to incorporate certain key variables based on the measurement of their probabilities in real life. These variables included the actual arrival of airplanes, the type of check required, amount of workload for any given type of check, and manpower availability. Other factors, such as usable working crew sizes and various decision rules, were also introduced.

Actual simulation is achieved through use of a 704 computer, using the Monte Carlo technique of breathing life into the station data, along with probability tables which were gathered directly from the field. To give some idea of the complexity of the model—it took IBM nine months to program it even after our study team had flow-charted the logic and successfully performed a hand simulation. The model can simulate 100 days' operation at any one of our major stations in eleven minutes. It is, to our knowledge, the "granddaddy" of large business models and has sparked the use of simulation in problem solving and business games.

Use of the model in its present form is fairly simple, in that input consists of including the combination of various factors which we are trying to optimize, along with the probability tables which describe the real-life variables for the process at a given station. The output is as indicated on Exhibit II. It must be compared for successful runs to arrive at an optimum combination of input factors.

For example, trip performance in terms of trip delays by flight number must be weighed against the cost of manpower or facilities. Most of the output reports are in the form of frequency distribution by hour of the day, providing a clue to further changes in input to reach a better economic and quality combination.

In one way we are glad that the model did not take an analytical form since, in its present state, it can be understood and used by our chief mechanics, station managers, and other staff people. The major purpose of the station model is to evaluate new ideas and concepts in maintenance policy, reserve airplane assignments, allowances for ground time between arrivals and departures, manpower planning, and facility requirement. The model itself does not produce new ideas. It does help evaluate them and show what is needed to implement them. The results of its use in helping to improve our service and reduce our costs makes our investment in it appear infinitesimal.

Our work in this area has convinced us that people working in the management field can at long last look forward to a means of trying to understand the complex systems which they manage and of evaluating new ideas and proposed changes in a system—ideas which in most cases would be too expensive, risky, or impossible to test.

The concept of one over-all business model appears to be a bit of "blue sky" at this point, but I see no reason why we cannot focus our attention on developing models which can at some later date interact directly with one another. For example, we have our station model, which represents a primary part of our operation. On the other hand, we have models which simulate the flow of people at our airport terminals, and the flow of information through our reservations system, and the flow of aircraft engines through our maintenance base.

A BLUEPRINT

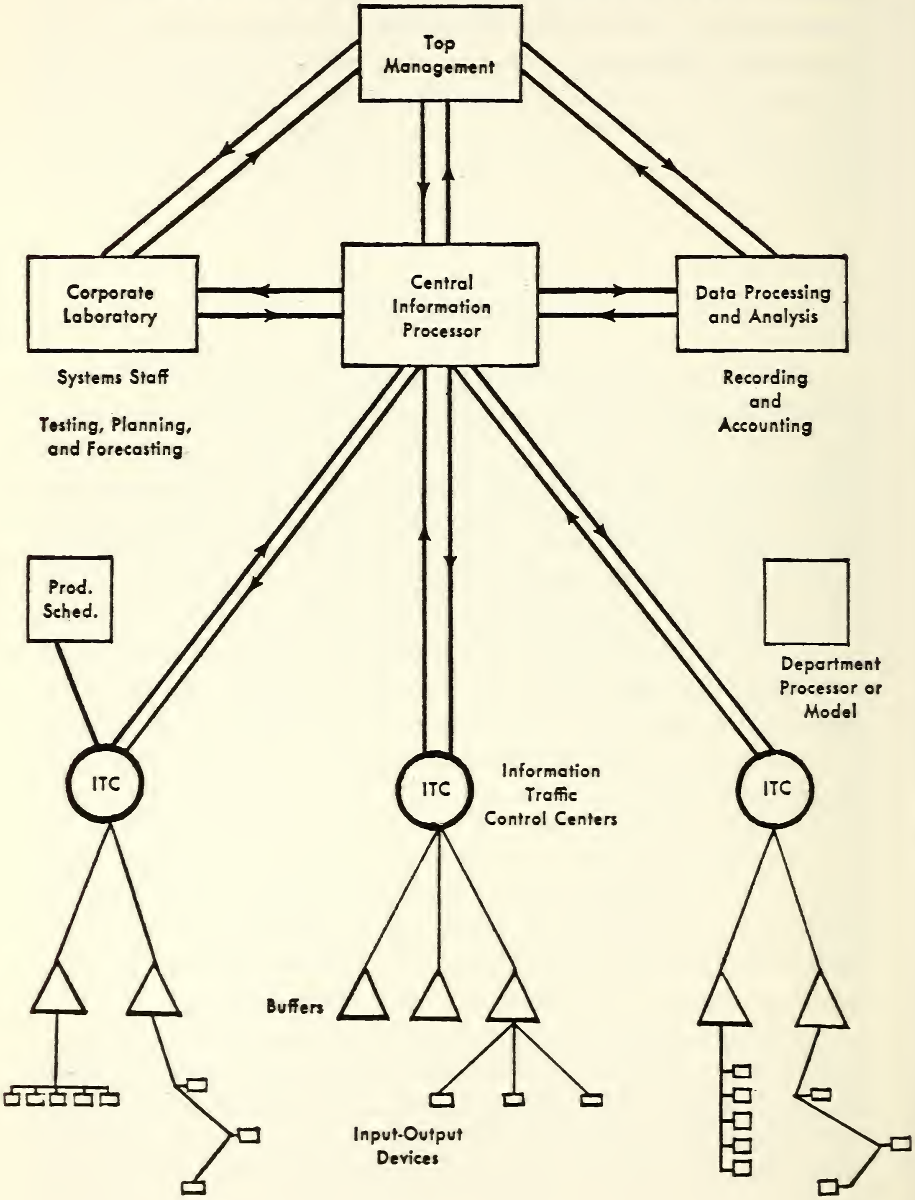
We are at a point in our work where many things seem to be falling into place, and I would like to sketch some sort of blueprint (see Exhibit *III*) or plan of what we consider a typical information system. You will notice, first of all, a basic data-processing communications system with the traffic controlled automatically by what might be called data control centers. These directly service input-output devices, which in our case may be in the flight dispatch offices, reservations offices, overhaul shops, storerooms, etc.

The basic processing of data would be done by a central information processor; however, we do recognize the need for specialized processors which may or may not tie into the system. For example, our flight planning computer, which will compute the best flight plan for our jets to fly, is such a processor. Since the bulk of the central information processors' capacities will be tied up in real time operation, it will have to spin off basic data which then can be processed and analyzed in what I would call the regular data processing and analysis group. This is the area where most of the computer applications to date have been made, and involves primarily recording or accounting functions.

In the other side, however, is what I call the corporate laboratory, which contains a staff and the models that are used to test and plan over-all company operations. For example, there may be a corporate finance model or a distribution system model; and some of these models, once developed, will become real time operation devices for planners or schedulers in a particular depart-

EXHIBIT III

BLUEPRINT OF A TYPICAL INFORMATION SYSTEM


Top Management
Corporate Laboratory
Central Information Processor
Data Processing and Analysis
Systems Staff
Testing, Planning, and Forecasting
Recording and Accounting
Prod. Sched.
Department Processor or Model
ITC
ITC
Information Traffic Control Centers
ITC
Buffers
Input-Output Devices

ment and should be given to them as a management tool. Tied in with this corporate laboratory is the staff, which is capable of analyzing company-wide system problems and developing concepts or models, if necessary, so that they can understand them better, make necessary process changes, or develop new concepts or policies.

We in United feel that we are already a long way toward filling in this blueprint. First, the staff functions of work measurement, systems engineering, quality control, operations research, data processing, and organization planning are all integrated under one head and are free to serve the entire company. This staff, it must be remembered, is really our research and development function; and once the tools have been developed and the analytical work completed, we feel that the continuing function or work should be assigned to the department and level where it can most practically be carried out.

We also recognize that most of these functions require specialists in groups in the operating areas and that our job is to bring an over-all company viewpoint and the latest technical skills to the area in order to maintain the company's productivity. As you can see, we are neither for centralization nor against decentralization. We think each company must solve these questions in the light of its particular situation. These themes lose some of their impact when one recognizes that computers can be assigned different tasks and have different levels of intelligence. Yet, they can be tied together by a master data communications system. In looking at the blueprint, one can easily visualize the passing down of plans, programs, and projects, and, in turn, a feedback of the type of information which will enable the corporate laboratory to refine its models and really maintain a continuing projection of the course of the business, assisting management in making the kind of decisions it must make along the way.

SUMMARY

Computers and data-processing technology will have less effect on organization than the systems analysis which should precede their use. It is in the search for better measurement and over-all understanding of business systems that the requirements for new information systems will be discovered, along with their resultant impact on organization. Furthermore, if industry is to maintain an ever increasing level of productivity, its research and development effort on the systems by which it produces must somehow approach its research and development effort on physical products.

STANDARD OIL COMPANY (NEW JERSEY): TECHNICAL DEVELOPMENTS

By

M. H. Grosz[*]

BROAD INTEGRATION OF SYSTEMS is now the accepted approach to gain maximum benefit from electronic data-processing facilities. Companies that have converted narrow-scope systems using punched-card equipment or manual methods without integrating related activities have usually been disappointed with results. Integrating systems while planning for use of electronic data-processing machines is a complex and difficult undertaking. Integration of systems calls for a high degree of co-operation by the various members of management responsible for the activities affected. As the scope of integration is increased, the span of co-operation increases rapidly.

The technical aspects of information technology are greatly advanced by electronic data-processing facilities. Superhuman assimilation of data becomes possible to aid in the solution of management problems. Centralization of data processing becomes very attractive. However, the information to be assimilated must be quantified if we are to advance very far in assisting managements with their more complex responsibilities. For the purpose of this discussion, we shall consider "data" to be the results of quantifying

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"information." It serves no purpose in the utilization of electronic data-processing facilities to quantify information if it is not properly identified ("tagged") for processing in an orderly fashion. All data to be co-processed must be tagged with compatible coding. If a standardized code structure is not available (and it normally is not), translation of compatible codes to a standardized structure is necessary before co-processing data from several sources. From this it can be seen that the scope of systems integration is largely dependent on the ability to adopt compatible code structure.

Several years ago, when the first large-scale electronic data-processing machines were delivered for business use, it was considered very ambitious (if not risky) to integrate systems at a plant level. Such integration is now an accomplished fact. The case that follows is an example of plant-level integration. The benefits from systems integration at the plant level have encouraged extensions of integration to broader levels. Today, there are a number of examples in industry of company-wide systems integration available for review. Integration of systems when companies are not related organizationally will have to wait for co-ordination by mutual consent. The submissions of Social Security data and federal income tax data to the U.S. Government are examples of integration at this highest level. There is urgent need for national standards in coding structure and procedures, as well as in business document forms design. The recent adoption of check specifications by the American Banking Association is an indication of what can be accomplished in this area. Purchase orders, invoices, shipping notices, bills of lading, etc., deserve the same attention. To integrate systems broadly, these requirements will have to be satisfied. Advancements in information technology will depend upon success in promoting these developments.

AN EXAMPLE OF INTEGRATED DATA PROCESSING AT THE PLANT LEVEL

The case material in this paper is based on experience with one project from a seven-project "EDPM Master Plan" installed at one of our largest petroleum refineries.

Our experience with mechanized data processing dates back to 1939, when we acquired a modest installation of IBM punched-card equipment. This installation was located in and operated by the accounting division and was devoted entirely to accounting operations. The installation was gradually enlarged, particularly immediately following World War II, as more and more of our accounting work was mechanized. By 1952, we had one of the largest punched-card installations in the South. Throughout this entire period we had concentrated on the mechanization of accounting work and had produced rather impressive results; accounting division personnel was reduced from 263 employees on January 1, 1946 to 174 employees on January 1, 1952. This record was forceful evidence that mechanization of clerical activities is a potent means of cost reduction, and resulted in a plant-wide interest in extending mechanization beyond the accounting function. As a result of this interest, we began a gradual expansion of our data-processing activities to other departments until, by mid-1953, a considerable amount of non-accounting work was being done on our IBM equipment.

About this time we backed off and took a fresh look at our data-processing activity. We were not too happy with what we saw. Through a process of evolution we had built up a system of small pieces: we had mechanized on a departmental basis rather than on an integrated functional basis. Study of the problem clearly indicated that maximum benefit from mechanization could come only from development of an integrated functional system crossing departmental lines, and this study led to the development of a basic framework for an integrated data-processing system. It was evident to us that the conventional punch-card equipment lacked the flexibility and speed to implement the integrated system which we envisioned. This led to the consideration of electronic data-processing equipment. I will not burden you with the details of our feasibility study. Suffice it to say that we eventually ordered an IBM 705 EDPM.

I would like now to briefly describe our "EDPM Master Plan" for business data processing. This is really an over-all integrated system composed of several integrated systems. Our study showed that the clerical or "paper work" activities of our plant fell into seven broad categories, each of which could be developed as an integrated system. We designated each of these categories as a project. They are described below.

Project M—Material and Stores. The Material and Stores Data-Processing System provides maximum mechanization of stock level control records, automatic purchase order preparation and follow-up, automatic invoice verification, and preparation of accounts payable checks. This project was put in production in July, 1956. The Material and Stores Project is the one we will discuss in detail later.

Project P—Payroll and Personnel. This project includes maximum mechanization of all information pertaining to our employees. The payroll portion of this project involves manpower planning and includes preparation of predicted daily work schedules, a day in advance, for all wage earners. Corrections to prediction are fed back into the 705 to adjust the prediction to actual, thus permitting the accumulation of actual hours, shifts, and rates worked. This history is then used in the payroll finishing operation for the preparation of pay checks, payroll registers, tax registers, etc. The payroll portion of the project was put into production on the 705 in July, 1956. The personnel inventory production of the project, which is not yet in full production, provides a basic record for each employee for the accumulation of all personnel history from which personnel statistics, seniority lists, etc., can be produced.

Project S—Sales and Shipping. Through the use of the IBM 705, customer data and shipping data are processed for maximum mechanization of the entire sales and shipping function. This includes scheduling of lubricating oil blending and grease manufacture, scheduling of container filling operations, optimization of package warehouse facilities, and scheduling of shipping. In addition, the 705 produces shipping papers, package inventory reports, customers' invoices, sales statistical reports, and the necessary accounting entries to reflect sales to our customers. This project went into production during the early fall of 1958.

Project O—Operations Analysis. Through the use of the IBM 705 we are able to maximize mechanical preparation of operating data, product and crude oil inventories, and laboratory data. Basic process data are fed directly to the 705 for the production of daily and monthly reports. In addition, the project permits the accumulation of historical operating information to be used for operations research studies designed to improve the profit position of the refinery. This project has just been put into production.

Project A—Fixed Assets. This project involves maximum mechanization of fixed asset reports and records, and permits us to eliminate the maintenance of approximately 30,000 manually posted cards which underlie our plant accounting records. The project was put into production on the 705 during July, 1956.

Project F—Financial and Cost. This project covers the general accounting and financial and cost report preparation. Each of the other projects feeds basic accounting data to this project for processing and determination of the necessary accumulations for accounting entries and report preparation. In addition to reports, the project produces voucher registers and the general and subsidiary ledgers. The Financial and Cost Project was put into production on the 705 in 1956.

Project E—Secondary Reports. This project provides for collecting and organizing data for the preparation of reports that cannot be conveniently produced directly in the other projects. In so doing, it makes it possible automatically to draw together data from all other projects for common processing. The Secondary Report Project was put into effect in July, 1956. Additional reports are being continually added to the system.

Technical Computing. In addition to the seven projects included in our Integrated Business Data Processing System, we are using our IBM 705 computer to a considerable extent in scientific computing and economic studies. Some of the more complex technical work is done on an IBM 704 operated in Linden, New Jersey, by our affiliate, Esso Research and Engineering Company.

We will now examine one of these projects in some detail so that you may get a firmer understanding of what we have done.

PROJECT M—MATERIALS AND STORES

As in the case of our other projects, a team of methods analysts and programers (in this case, two men) was assigned to the Materials and Stores Project on January 1, 1955. They spent several months on the systems development phase. Their approach was to analyze systems *requirements.* In doing this, they paid little attention to the HOW of the old system and concentrated on the WHAT and WHY. The objective was to develop an EDPM system to satisfy all requirements and to build in "management by exception" features to the greatest extent possible. About four man-years were required to develop the system and write the two basic programs for the project. The first of these programs is devoted to stock level control and purchase ordering, while the second program accomplishes purchase order follow-up and the accounts payable function.

Stock Level Control and Purchase Ordering. We have in our storehouse some 30,000 items of maintenance and operating supplies. In addition, we have about 5,000 items in our central tool inventory that are also controlled by the EDPM system. The system is so designed that any material subject to stock level control can be added. We are now in process of adding about 4,000 items of laboratory supplies for our research laboratories.

While the program was being written, a master record was being developed by our stores and purchasing departments for each of the items to be included in the system. This was a major task, involving several man-years of work before we finally created our starting master tapes. The record for each item contains up to 931 characters of information. This includes symbol number, full alphabetic description and size, name and address of the preferred supplier, quantity and cash discount terms, several control points (ordering point, minimum, emergency point, etc.), and a considerable amount of historical information on issues and receipts. These records are on tape in sequence by symbol number. Our symbolization system provides for an eight-digit stock number: the first two digits represent the main class of material, the next two digits identify the subclass of material, and the last three digits identify individual items within the subclass.

Each day we keypunch cards on all transactions affecting all items in the automatic stock level control system. Examples of transactions are receipts, issues, inventory adjustments, transfers, new item additions, deletions, and all changes to the basic master record, such as changing from one supplier to another. These cards are sorted to symbol number sequence so that they are in the same sequence as the master records on tape, and then are put on magnetic tape in an off-line operation for subsequent feeding to the 705.

The following briefly (and partially) describes the functions performed by our stock level control program:

1) The imput master records are read into memory sequentially.

2) Current transactions are posted to the master records. This posting operation is actually a modification of the master record; the individual transactions are not recorded in the master record. For instance, receipts increase the quantity and dollar balances, and issues decrease quantity and dollar balances. A transaction record involving a change in supplier merely substitutes the new supplier for the one formerly included in the master record.

3) The master record contains counters for the accumulation of issue and receipt information, and these counters are modified for transactions affecting them.

4) After each invoiced receipt is posted to the master record, a new average price is calculated and replaces the old average price.

5) In processing issue transactions, the quantity is multiplied by the average price in the master record to arrive at the value of the issue. The issue transaction record contains the account code to which the item should be charged, and at this point a material cost distribution entry is written on an output tape unit. Here one begins to see signs of the integration we have developed between the several projects in our system. This cost distribution record will eventually find its way into our Financial and Cost Project. We think that one of the greatest virtues of our system derives from the fact that the output of one function becomes the input to another function.

6) After all transactions for the particular symbol number have been posted, the modified master record is examined by the program to determine whether the ordering point has been reached.

7) If the ordering point has been reached, a purchase order can now be written, since the master record contains all constant information needed in ordering. Our program is so written that all items to be ordered from the same supplier within the same main class of material will be combined on one purchase order. Another feature

of our program is the "can-order point." If an item is approaching the ordering point and we must order another item from the same supplier in the same class of material, the "can-order" item will also be ordered.

8) Although the system is basically automatic, our stores and purchasing people frequently need to know the status of items in the system. Remember that the master record tape file is actually a *current* stock ledger, and that there is no other record to which they can refer. By filling out a simple form, which is later key-punched as a transaction, stores and purchasing personnel may "call-out" of the system the complete master record for any item or block of items. In addition, the program itself recognizes certain conditions which require human intervention. An example of this is a negative bin balance, an impossible situation that requires investigation. The print-out form (see Exhibit I) contains a series of blocks representing the various reasons for which print-outs are required, and an "X" is printed automatically in the appropriate block. The forms can thus be directed to the proper individual or group for investigation. This investigation may or may not, depending upon circumstances, generate feedback data.

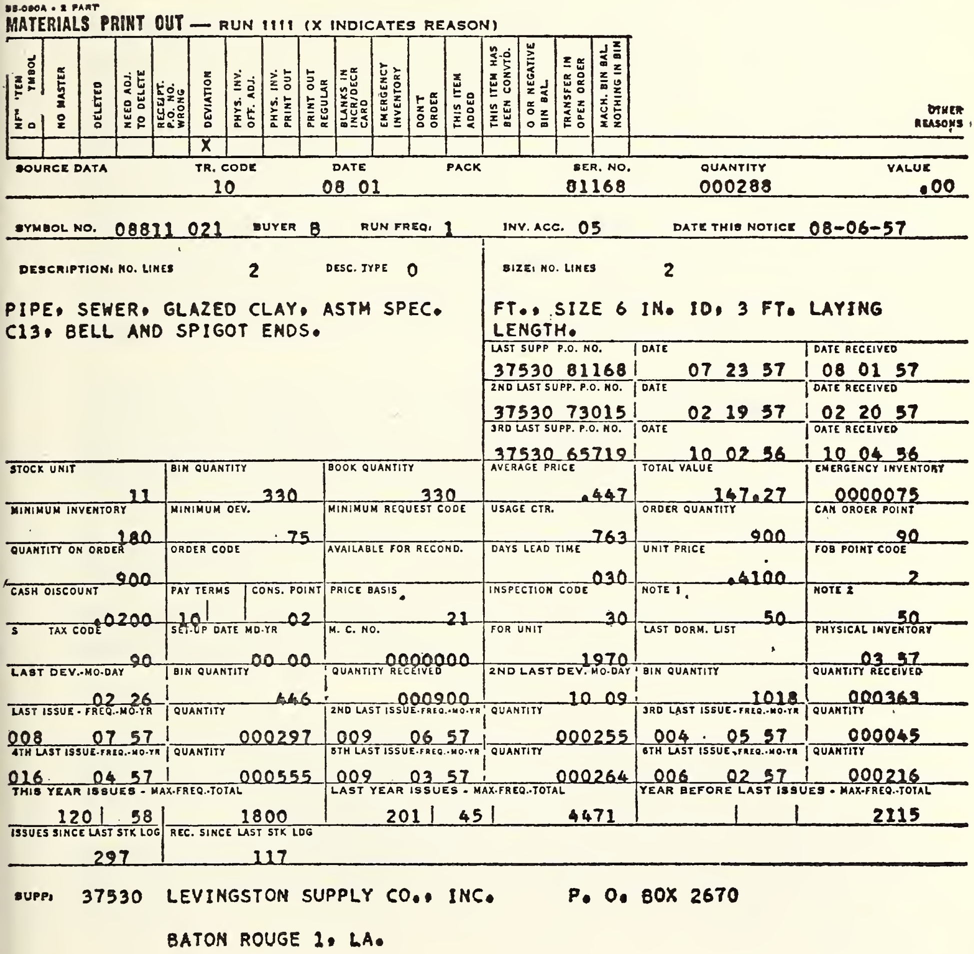
9) For each item which appears on a purchase order, a card is punched out. These cards will become input to our purchase order follow-up and accounts payable run.

Purchase Order Follow-up and Accounts Payable. The program to accomplish purchase order follow-up and accounts payable operations contains some 6,000 instructions. The master file represents all open purchase orders and the file is in sequence by supplier number, purchase order number, and purchase order item number.

Remember that the automatic stock level control run has ordered only stock items. The purchasing department also manually writes purchase orders for non-stock items. These are the non-repetitive items, usually tailor-made to specifications, which do not lend themselves to automation because they are non-recurring. However, the pertinent details of these orders, including price and terms, are also key-punched and included in the system, so that the manual orders may receive automated treatment in the subsequent phases of the operations. In addition to new open order transactions, the feed to this run includes receipts and supplier invoice data cards.

Let me describe now the *purchase order follow-up* function of the system. Automatic routine tracing of all orders (for both stock and non-stock orders) is accomplished by pre-establishing in the program a pattern of practical follow-up intervals and the text of several tracer letters appropriate to the different situations which may

EXHIBIT I



SS-090A • 2 PART

MATERIALS PRINT OUT — RUN 1111 (X INDICATES REASON)

NF ITEM SYMBOL D	NO MASTER	DELETED	NEED ADJ. TO DELETE	RECEIPT. P.O. NO. WRONG	DEVIATION	PHYS. INV. OFF. ADJ.	PHYS. INV. PRINT OUT	PRINT OUT REGULAR	BLANKS IN INCR/DECR CARD	EMERGENCY INVENTORY	DON'T ORDER	THIS ITEM ADDED	THIS ITEM HAS BEEN CONVTD.	0 OR NEGATIVE BIN BAL.	TRANSFER IN OPEN ORDER	MACH. BIN BAL. NOTHING IN BIN	OTHER REASONS
					X												

SOURCE DATA	TR. CODE	DATE	PACK	SER. NO.	QUANTITY	VALUE
	10	08 01		81168	000288	.00

SYMBOL NO. 08811 021 BUYER B RUN FREQ. 1 INV. ACC. 05 DATE THIS NOTICE 08-06-57

DESCRIPTION: NO. LINES 2 DESC. TYPE 0

PIPE, SEWER, GLAZED CLAY, ASTM SPEC.
C13, BELL AND SPIGOT ENDS.

SIZE: NO. LINES 2

FT., SIZE 6 IN. ID, 3 FT. LAYING
LENGTH.

LAST SUPP P.O. NO. 37530 81168	DATE 07 23 57	DATE RECEIVED 08 01 57
2ND LAST SUPP. P.O. NO. 37530 73015	DATE 02 19 57	DATE RECEIVED 02 20 57
3RD LAST SUPP. P.O. NO. 37530 65719	DATE 10 02 56	DATE RECEIVED 10 04 56

STOCK UNIT 11	BIN QUANTITY 330	BOOK QUANTITY 330	AVERAGE PRICE .447	TOTAL VALUE 147.27	EMERGENCY INVENTORY 0000075
MINIMUM INVENTORY 180	MINIMUM OEV. 75	MINIMUM REQUEST CODE	USAGE CTR. 763	ORDER QUANTITY 900	CAN ORDER POINT 90
QUANTITY ON ORDER 900	ORDER CODE	AVAILABLE FOR RECOND.	DAYS LEAD TIME 030	UNIT PRICE .4100	FOB POINT CODE 2
CASH DISCOUNT .0200	PAY TERMS 10 CONS. POINT 02	PRICE BASIS 21	INSPECTION CODE 30	NOTE 1 50	NOTE 2 50
S TAX CODE 90	SET-UP DATE MO-YR 00 00	M. C. NO. 0000000	FOR UNIT 1970	LAST DORM. LIST	PHYSICAL INVENTORY 03 57
LAST DEV.-MO-DAY 02 26	BIN QUANTITY 446	QUANTITY RECEIVED 000900	2ND LAST DEV. MO-DAY 10 09	BIN QUANTITY 1018	QUANTITY RECEIVED 000363
LAST ISSUE - FREQ.-MO-YR 008 07 57	QUANTITY 000297	2ND LAST ISSUE-FREQ.-MO-YR 009 06 57	QUANTITY 000255	3RD LAST ISSUE-FREQ.-MO-YR 004 05 57	QUANTITY 000045
4TH LAST ISSUE-FREQ.-MO-YR 016 04 57	QUANTITY 000555	5TH LAST ISSUE-FREQ.-MO-YR 009 03 57	QUANTITY 000264	6TH LAST ISSUE-FREQ.-MO-YR 006 02 57	QUANTITY 000216

THIS YEAR ISSUES - MAX-FREQ.-TOTAL			LAST YEAR ISSUES - MAX-FREQ.-TOTAL			YEAR BEFORE LAST ISSUES - MAX-FREQ.-TOTAL		
120	58	1800	201	45	4471			2115

ISSUES SINCE LAST STK LOG	REC. SINCE LAST STK LOG
297	117

SUPP. 37530 LEVINGSTON SUPPLY CO., INC. P. O. BOX 2670

BATON ROUGE 1, LA.

arise. In the case of the stock items, a lead time for each item has been established in the record, because lead time is a function of the reorder point. In the order-writing phase, the computer added this lead time to the order date and printed a due date (date delivery is required) on the purchase order. In the case of the non-stock items ordered manually by the purchasing department, a due date is entered on the order as a matter of course. Having both an order date and a due date for each open order, and guided by the follow-up intervals, the program works forward from the order date in tracing for an acknowledgment and a shipping promise, and backward from the due date in asking "Will you deliver on the date requested?" Receipt of material or receipt of an invoice automatically stops follow-up. All shipping promises received from suppliers are key-punched into the system; the program compares these with due date; if the promise agrees with the due date, within a reasonable tolerance, the machine accepts the promise; if the variation from the due date is significant, it prints out a notice to purchasing where expediters then pursue the matter further. Under the principle of "management by exception," the purchasing department acts only on the problem cases which are called to its attention. No time or effort is wasted on the items which will be delivered on time.

In the same 705 run which performs the purchase order follow-up function, we also accomplish *automatic checking and payment of suppliers' invoices.* In addition to basic purchase order data, the open order master tape record provides spaces for bringing in receipt and invoice data. Orders remain on the tape in "open status" until the material and the invoice have been received and all the built-in checks of the system have been satisfied. The following is a partial list of the functions automatically performed in the accounts payable phase of the program:

1) Quantities received and quantities invoiced are checked against quantities ordered. Space is provided in the open order master tape for multiple partial receipts and invoices.

2) Invoice prices, f.o.b. terms, cash discount, and pay terms are compared with prices and terms previously recorded from the purchase order.

3) Invoice price extensions and the totals of invoice items are verified.

4) Freight terms shown on invoices are verified.

5) The propriety of sales tax charges appearing on invoices is established; sales tax calculations are verified; and use tax is accrued if applicable.

6) Trade discount calculations are verified, and cash discount amounts are computed.

7) If invoices survive all of the built-in verification steps, or meet certain qualifying exceptions, an accounts payable check is printed. There are many of these exceptions built into the system. For example, if the invoice is received before the material is received, the invoice is recorded in the master tape in a "suspense" status. Payment will be suspended until the date that the invoice is due for payment under the pay terms. The system will pay the invoice either on receipt of material or on the due date, whichever occurs earlier. If the due date arrives first, the invoice is paid on the basis of "material-in-transit" and the undelivered items are listed on a daily audit report pending their receipt. At the end of the month, the system lists all items still in transit; this list also shows all items received but not invoiced. From this list, accounting entries may be made and appropriate follow-up steps may then be taken to track down missing material and invoices. I cite this example to give an idea of the extent to which our system is automated.

In the writing of accounts payable checks the system provides for grouping all payments to a single supplier, with the individual invoices being listed on the "remittance statement" portion of the check form. Credit memos from suppliers are also included in the system; they are held in the open order tape until a payment is made to that supplier, and will then be deducted as an item on the remittance statement.

8) Accounting entries are generated distributing payments to suppliers. These entries are in the form of magnetic tape output, and will later become input to our financial and cost runs.

9) "Invoice receipt" cards on stock items are generated for feedback to the stock level control run so that the dollar balances and average prices of stock item master records may be modified.

10) The steps listed above for invoice verification are basically

comparisons of invoice data with information in the open order master tape. If, in any of these steps, invoice data does not agree with master record data, or fails to meet certain built-in tolerance tests, the invoice record is rejected. When this occurs the computer prints out an exception notice for investigation. Here, again, is an example of the "management by exception" principle.

That describes our Materials and Stores Project. We think it is a good, solid system that contributes to the better management of our business. But we are not complacently satisfied with it; we are continually modifying, refining, and expanding the system. While we have made rather substantial manpower savings from the Materials and Stores Project, we are also making noteworthy strides in the realm of the application of the theory of good purchasing and materials management. In fact, there is a growing feeling that these theoretical factors, rather than manpower savings, should be considered as the primary objective of the automated system.

[*Comments made at the Seminar by Mr. Grosz as a supplement to his paper*]

A PLANT LEVEL PROJECT

Having described our Project M in detail in my paper, I might add a bit about Project P: Payroll and Personnel.

In this project, we had two major goals: (1) to reduce the tremendous duplication of personnel records at the refinery level, and (2) to assist supervision in assigning people to their jobs.

We had, at this time, about two thousand process workers and three thousand mechanical workers to be assigned to jobs each day. This is quite a complicated task. On the one hand *operating* personnel must keep their stations manned constantly. The result is a complex structure of work schedules. Since no man can leave his job until he has been relieved by another, we must build schedules on the basis of 4.2 men to the job. In the case of *mechanical* (maintenance) people, on the other hand, we have a different problem. These people are not scheduled to specific jobs on a regular basis. Any assignment system for them must be quite flexible.

The assignment system starts with a daily print-out to each foreman, showing the men assigned to him that day, their rates of pay, and hours of work. This simply transfers our former assignment system into the computer and does not represent a reduction from previous practice.

Even so, we found that we could schedule 5,000 people each day in a ten-minute run on the 705. This brief run schedules maintenance people not only to their job assignments for the following day, but also for the day after that, so that supervisors can plan ahead to some extent. The foremen, upon getting these sheets, examine them, make any corrections necessary, sign them, and send them back. These corrections have been running at a rate of about seventeen per cent of the original total entries. Corrections are then key-punched and, with the original schedules tape, form the basis for our payroll run.

This payroll run has several parts. We must carry a seventeen-day span of information on every workman in what we call a time-keeping run. This is necessary in order to assure the administration of various provisions in our union contract. We have developed a program which administers the rules in the union contract on work assignments and compensation. At the end of this cycle of daily runs we then have the information needed for preparation of payroll.

What I have described in my paper is essentially an integrated system at the plant level. Each of the seven major systems described has an output which enters directly into daily refining operation (Figure 1). In addition to this direct output, there are accounting entries of one type or another fed into a financial project for the preparation of the profit and loss statement and balance sheet. We get, in addition, a variety of statistical data from these seven projects. We have pooled all our report requirements to be satisfied from a single system. We extract simultaneously from all tapes all the information we need for all statistical reports.

Company Level Projects

Having demonstrated the advantages of systems integration at the plant level, we now have under development systems to be integrated company-wide. Also, we are in the process of developing systems to be integrated across corporate lines. Until these systems are developed to an operational stage, we prefer to restrict discussion, for rather obvious reasons. There is always the possibility that projects under development may never reach the operational stage.

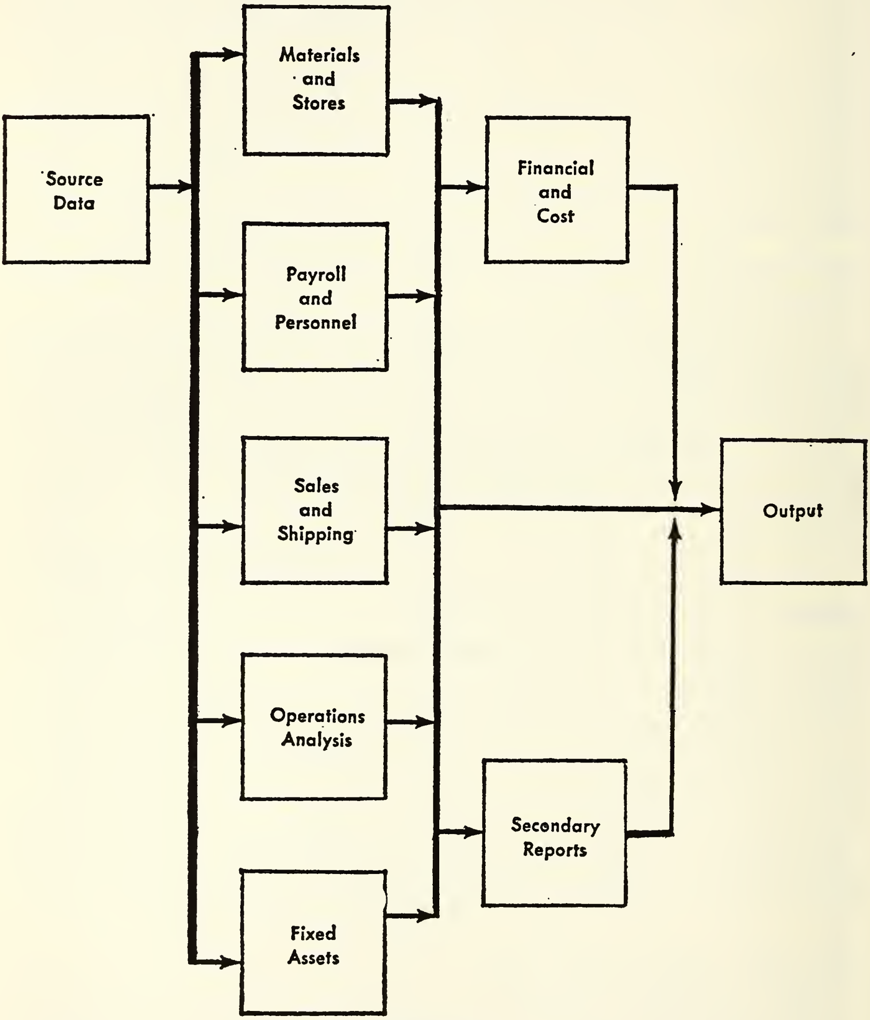

Source Data
Materials and Stores
Payroll and Personnel
Sales and Shipping
Operations Analysis
Fixed Assets
Financial and Cost
Secondary Reports
Output

Figure 1

Information Processing System: Plant Level

STANDARD OIL COMPANY (NEW JERSEY): ORGANIZATIONAL DEVELOPMENTS

By

Carl H. Rush[*]

In this paper I shall describe in varying degree some of the effects, influences, or concomitants of information technology and its growth in the Standard Oil Company (New Jersey), which will henceforth be designated "Jersey Standard." In so doing, I shall give minimum attention to the technical aspects of our information systems, leaving that in the more capable hands of my colleague Mel Grosz, and concentrate on things which have happened within our company as a consequence of changes in such information systems. As a further ground rule, the basic definitions of information technology and related concepts as set forth in the paper by Whisler and Shultz will be accepted and used without elaboration.

This paper will consist of three main sections: (1) a description, with examples, of the present situation regarding changes in organization, personnel, policies, practices, etc.; (2) some observations pertaining to factors which may serve to inhibit temporarily the development of information technology in our company or in any company; and finally (3) some brief speculations about the future impact of radically altered information systems. Before moving into these three sections, however, it would seem desirable to create a setting by devoting a few paragraphs to a brief description of the company and its operating principles.

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THE COMPANY

The basic characteristics of Jersey Standard are probably known to all Seminar participants. It is one of the world's largest corporations. It has over 200 affiliates, of which over ninety are directly owned; it markets petroleum products in 135 countries and dependencies; it has 214 million shares of stock held by half a million shareholders; and it bears no corporate relationship to any other "Standard" company. The parent company is exclusively a management organization existing solely for the purpose of co-ordinating the efforts of its affiliates. As such, it is the focal point for vastly complex information systems which must be integrated and interpreted to guide management decisions.

The following statement should be sufficient to complete this description of the company:

> Standard Oil Company (New Jersey) is an American commercial enterprise which was incorporated in 1882, and throughout its history has applied its resources and energies to the petroleum industry. Though its interests are world-wide, the management has always been situated in the United States and the bulk of its corporate assets located in the Western Hemisphere.
>
> Standard Oil Company (New Jersey) is the parent company in a large family of affiliated companies which together supply about one-sixth of the petroleum products used in the world outside the communist countries. The business of Jersey, the parent company, is investment in the broad field of petroleum industry, the management and coordination of its existing investments, and the constant search for profitable new investments. The operating functions are performed by the various affiliates, in most of which Jersey is the majority shareholder, and in many the sole shareholder.
>
> Throughout the Jersey family decentralization of management is a basic principle. Each affiliate manages its own operations. Each has its own board of directors and officers who are responsible for the success of the affiliate's operations.

Jersey makes available to each affiliate appropriate results of its research and that of other affiliates in technology, economics and other fields. It reviews with affiliates their financial affairs, operating results and executive development programs, and attempts to assure that each affiliate selects well-qualified executives. It reviews their objectives and in certain areas sets basic policy to help affiliates reach objectives in the interest of all their shareholders.

COMPANY DEVELOPMENTS IN INFORMATION TECHNOLOGY

Computers, integrated data systems, operations research techniques, and applied mathematics are, perhaps, not familiar terms in the vocabulary of every employee, but they are by no means strange terms in Jersey Standard. As of this writing, Jersey has six large-scale (IBM 700 series) and twenty-two smaller computers installed. In addition, four large-scale and seven other computers are on order. It is estimated that in 1960 the annual rental for computers in Jersey will amount to about 6½ million dollars. The majority of these existing and planned installations are located in the United States but there are important installations in Central and South America, Western Europe, and the Middle East.

Quantitative description of developments in integrated data systems is difficult, and, since this term is closely associated with computer usage, it is enough to say that there are massive efforts currently being made in Jersey to achieve integration. We shall have more to say of this later, when it will be apparent that integrated information systems are being sought in many fields.

Applied mathematics and operations research techniques have been used in virtually all functions of the company: production, transportation, manufacturing, marketing, engineering, and research. A recent compilation shows they have been used in ninety different applications within the company. The number of people engaged full time in these activities is still rather small (probably less than 200), but such figures are deceptive because of the growing tendency for these techniques to be employed occasionally by a much larger number of people. Here again the computer plays a central role, for it has brought operations research and applied mathematics out of the academic, theoretical realm and into practical application. Almost all operations research work in the company today involves the use of a computer, as was seen at a recent meeting on mathematical techniques at which ninety per cent of the papers mentioned the use of a computer in a specific project.

Perhaps the best example of the marriage between computers and operations research exists at several of our largest refineries, where linear programing models have been developed to calculate motor gasoline blends. These models permit the calculation of blends which meet all specifications with minimum loss from "product give-away" (going beyond minimum specifications on some requirements). One of the refineries now has a small computer which does nothing but calculate blends in what amounts to an on-line operation.

Organizational Mechanics

With the rapid growth in procurement and use of computers, the company has created several important committees which should be mentioned here. The first of these is the Systems Development and Co-ordination Committee, made up of key representatives from the fields of data processing, technical computing, and operations research. It also has a representative from employee relations because of the present and potential impact of these techniques on such problems as personnel displacement, employee and management training, etc. The responsibilities of this committee are the following:

> To provide a small co-ordination body of key personnel from the fields of systems development, applied mathematics, operations research, and electronic computing for the purpose of assisting the Jersey Systems and Methods Division carry out its responsibility for co-ordination of systems development and related activities among affiliates of Jersey Standard. This committee will provide broad planning and co-ordination. It will serve:
>
> 1. to expand the scope of planning so as to take advantage of intercompany opportunities (centralized computing facilities, systems integration, intercompany operations research projects, etc.).

2. to cut costs by better use of facilities (selection of computers and location of installation, unified dealings with computer manufacturers, etc.).
3. to reduce duplication of effort (in systems development, in computer programing, in operations research projects, etc.).
4. to promote participation in promising activities or in projects that have proven successful elsewhere.
5. to discourage participation in activities not showing good results or in projects that have proven unsuccessful at other locations.

In addition to the committee just described, there are two major committees in the Western Hemisphere with equivalent groups in Western Europe: the Data Processing Committee and the Committee on Mathematical Techniques. These committees exist for the purposes of disseminating information concerning new techniques and applications and of creating uniformity and standardization among the affiliated companies which participate. Forums are held at regular intervals to further these purposes.

One final organizational arm, recently constituted, will conclude this section. The parent company has established a Reports Review Task Force whose directive is to seek means to achieve a "more efficient management information system." This committee will study intensively the entire input to the parent company, with a view toward utilizing all available techniques and tools in constructing an information system which will facilitate the management process. Because of the nature of this directive, this committee will work closely with all other aspects of information technology in the company; computer installations and operations research groups, as well as reporting affiliates.

In summary: I have tried to sketch very briefly the progress of Jersey Standard in utilizing information technology in its fullest meaning. The company has a large investment in computers and in the trained people who use them. Organizational units have been established to effect the necessary co-ordination in the various fields. I do not mean to imply that we have all the answers—indeed, the discussion to follow will argue to the contrary—my purpose is rather to create some understanding of the steps which have been taken.

ORGANIZATIONAL IMPACTS

We turn now to an examination of observable changes, problems, or influences which have accompanied the growing-pains of information technology. It will not always be possible to establish cause and effect relationships, but this will not be our prime concern. Instead, we will list and describe a number of conditions which exist in the company today. One should not attach any significance to the order in which these items appear here. Nor should these problems or topics be regarded as unique to Jersey Standard; undoubtedly they exist to greater or lesser degree in many other companies.

Changes in Organizations. At the present time it would be difficult to point to instances of radical organizational changes which can be attributed to increased sophistication in information systems. But there are signs of pressures which are building in such a way as to challenge the efficacy of existing organization structures. Computers and their staffs have been assimilated into existing structures, usually the comptroller's departments; the same is true of applied mathematics and operations research, except, of course, that the units to which these functions report vary considerably. In one instance, that of our Canadian affiliate, Imperial Oil Company Limited, the computer group was established as a completely new organizational unit reporting directly to top management rather than to an intermediate level. This is the exception rather than the rule, however, and since Imperial has not yet received its 705, the usual model may be established when the unit goes on stream.

Thus we can say that nothing drastic has happened, as yet; but I should like to discuss some rather subtle signs which predict future significant changes. The first of these has to do with the uneasy placement of computer units within comptroller departments. In most cases, the computer seemed to fit naturally and logically into existing systems and methods divisions of these departments; but such placement often sets the tail to wagging the dog. Budgets and personnel have expanded considerably, in some cases to the point where the computer units dominate, at least numerically, the more traditional units of the comptroller's department. As a result, there is a growing feeling that, once the computer becomes fully integrated into a given company (it is not as yet, as I shall point out later), it should be removed from the supervision of any one department and placed on an independent status. In other words, as the data-processing facility grows in acceptance and power, there is good reason to believe that it will assume a much different organizational relationship to its client departments.

While there is little evidence of sweeping change and no substantial diminution of the decentralization concept, present trends toward the integration of information systems will inevitably serve to break down barriers between major departments or organizations as they exist today. At some point these trends may lead to reorganization; today they are reflected only in an increased tendency for autonomous units to communicate with one another through integrated systems. To illustrate this point, I shall discuss some features of our approach to integration in the parent company, emphasizing the application with which I am most familiar, i.e., a master personnel information system.

In the parent company—which is, as I have stated, a co-ordinating, management company—we are building most of our work around four master systems: (1) petroleum statistics; (2) financial; (3) benefit plans administration; and (4) personnel information. The first is a highly complex system of data pertaining to supply of and demand for petroleum products. At present, this function is performed by several different departments and affiliates who receive data from many sources in our worldwide operations. The present system is characterized by much duplication, overlapping, and slippage, so that integration with a single point of entry and multiple outputs promises great increase in efficiency. The organizations affected are not being changed measurably, but they are co-operating actively in integrating their functions. Personnel from each of the participating departments and affiliates have been joined in a task force to perform the necessary systems and programing work.

The same general description holds for the benefit plans administration and financial systems, with obvious differences in the type of data and participating organizations. In order to clarify this integrating trend and its potential impact on organizational changes, I shall discuss in more detail our plans for a master personnel information system.

In the parent company and its affiliates, we are working toward an integrated electronic data processing system for all information pertaining to employees. As things now stand, information of this type is processed routinely in the parent company by the Employee Relations Department, the Personnel Office, the Plans Administration Office, Payroll, the Medical Department, the Insurance and Social Security Department, and, to a lesser extent, each operating department. We have organized a task force whose sole function is to build a 705 system which will integrate, into a single file, most of the personnel data currently being handled by these many departments. This file, which will be in full historical depth, will employ the single entry principle and will be programed with sufficient generality to serve the multiple needs of these various units. Present plans call for this system to be built in the parent company, but later extensions call for the adoption of uniform or compatible systems in affiliates to facilitate the consolidation of personnel information for the entire organization.

The point of this discussion is to show that this integration, not possible previously, will lead inevitably to changes in the relationships among departments and affiliates. We have already begun to think about the nature of a central organization which will operate this system, performing on an integrated basis those tasks which are now the responsibility of independent staff groups in each of the departments. This new organization probably will not be housed in any one of the participating units but will instead exist as a service group to all. This is an example of the kind of organizational change which will take place very early in the development of integrated systems irrespective of the nature of the data. Changes of this same sort will undoubtedly be made in connection with the three other master systems mentioned earlier.

Influences on Management Training and Development. Here, again, there are no earthshaking developments, but several trends deserve mention. In several installations, promising young men are being rotated through data-processing work as a part of their development. One of our largest refineries, which has had a long history of success with a rotation program, has extended the program to include a year or more of programing experience for future managers. These men come from various fields of work, learn to program the computer, and build at least one major system during their assignment with the data-processing unit. In the personnel information system mentioned above, the task force is made up of carefully selected young men from each of the participating departments (Personnel, Medical, Plans, etc.) who will return to their respective departments when the bulk of the development work is completed. The decision to constitute the group in this way was based on two premises: (1) that successful creation and ultimate use of an integrated system is dependent on the direct participation or "involvement" of people from the departments in question; and (2) that future managers of these departments must have a fairly high level of sophistication with regard to data-processing techniques.

In short, there is a growing realization in the company that managers of the future must have some awareness not only of the capabilities of electronic data processing systems but also of the technical aspects of systems construction and maintenance. Obviously, not all managers will have the opportunity to spend a year or two as programers; to compensate for this lack, several programs for management indoctrination have been developed. Some have been general, designed to communicate the broad concepts of electronic data processing to heterogeneous groups of managers (and employees, incidentally). Others have been much more specific, designed to accompany the development of systems in a particular department or function. To use the personnel information system again as an example—we have conducted and will continue to conduct training sessions for managers in which the details of the system are carefully explained. These sessions have the dual purpose of (1) creating support and acceptance for the many changes which will accompany the system's introduction, and (2) challenging the imagination of managers in terms of potential uses of the system.

One final development deserves mention here, even though some would argue that it has only slight relationship to information technology—the small but growing movement to employ operational gaming as a training technique for managers. We now have five or six such games in operation, ranging from a service station model used in training marketing personnel to a research strategy model played by managers in our research company. These games are related to the computer only in the sense that computations of plays are made on the machine, but their use began only after the computer and mathematical techniques had reached the present state of prominence.

Influences on Organization Principles. In the review of some of the management principles which are part of Jersey, decentralization and co-ordination were mentioned as important concepts. As we move toward integrated systems encompassing several departments and affiliates, as we develop and adopt uniform coding and classification schemes, it appears that co-ordination is assuming the dominant role, while decentralization wanes as a concept and as an operating reality.

Decentralization has often appeared vague and ambiguous, but until recently it permitted a non-functional type of uniqueness in which particular affiliates could do things differently for lack of any reason for uniformity. For the sake of broad systems compatibility, we can no longer permit the existence of non-functional differences in such areas as product codes, purchasing specifications, and many other data systems. And as we minimize differences, something is happening to the concept of decentralization. I do not mean to imply that co-ordination and decentralization are complementary concepts of the $p + q = 1$ variety; but there seems to be a point beyond which increased co-ordination inevitably influences decentralization.

Manpower Problems. There are a number of specific problems associated with personnel under conditions of modern information technology. The first is that of anticipating changes in the characteristics of the work force and modifying personnel inputs to meet these changes. For several reasons, personnel people have become aware that something is happening in these areas and have begun to ask intelligent but difficult questions. If the work force will be different in the coming years, what sorts of people should we now be hiring at the entry level? What specific skills should we be looking for and/or developing? These are very real and reasonable questions, to which we have only the crudest sorts of answers. Penetrating analysis of this problem is needed, but the salient point for the present discussion is that these questions have occurred to practical people whose business is making sure that the organization will be equipped in the future with the proper mixture of talents.

In any discussion of impact on personnel, one must include the problems of employee displacement, retraining, and morale. There is no question that computers will cause reductions in personnel. Indeed, as I will mention later, our computers have been justified almost exclusively on this basis of cost reduction. This is unfortunate, I feel, but it seems to be the one neat way of itemizing savings. Because of the advanced stage of technology in the petroleum industry, we have been through this type of displacement several times and adequate mechanics are available. It is true, however, that recent events have caused reductions of personnel in wage earner classes and this, combined with the threat of displacement of clerical workers, has resulted in serious apprehension in some quarters.

There is some evidence that morale has been adversely affected in several locations. Faced with the necessity of reducing personnel, management has been unable to give blanket reassurance concerning job security under conditions of mechanization, and the absence of any statement has probably hurt us somewhat. It is difficult to pinpoint causes or consequences of low morale, but there seem to be several areas in which a vague feeling of uneasiness characterizes employees' feelings. Partly because of impending reductions in clerical staffs and partly because of the long-term changes in the ratio of office workers to production workers, management has begun to realize the strength of the pressures operating to make organization of white-collar workers a reality. Labor leaders have indicated that this segment of the U.S. working population hold great potential for unionization, and strong efforts are being directed toward that end. To be sure, reduction in staff because of electronic data processing does not constitute the only motivation for organization; but it certainly provides labor with a persuasive argument.

One of the problems with which we have been faced is that of selecting and training computer personnel. Several aspects of this problem revolve around the lack of clarity concerning computer work as a career. We have not yet established career lines which show where a person goes after a successful period in computer work. As a result, some people, when asked to enter the field, have declined on the grounds that it would remove them from the "main stream" of the company. Others have said they do not want to be branded as "machine men" when their careers are in economics, accounting, plans administration, personnel administration, technical or scientific fields, etc. Yet these are often the very people we want, because of their subject matter experience and other qualifications.

Like many other companies, Jersey has obtained most of its electronic data processing personnel from within the organization. Some have obviously come from the outside, with prior training; but most have transferred from other work to be trained as programers, console operators, or in other occupations in electronic data processing. Our selection procedures are not uniformly good and some of our installations have made serious mistakes. Thorough screening with tests and interviews has produced much more satisfactory results. However, we have often found it necessary to screen many candidates from employee groups in order to find the people we want. In some cases, entire departments have been scrutinized in order to find two or three promising people. My point here is simply that the available resources from within the company are not unlimited, and considerable care must be taken lest we employ exactly the wrong kind of people for systems or computer work. By "the wrong kind of people" I mean those who, because of basic rigidities or years of exposure to old ways of doing things, cannot apply imaginative thinking to the development of data-processing systems.

FACTORS INHIBITING PROGRESS IN INFORMATION TECHNOLOGY

I should like to turn now to a discussion of factors which appear to be inhibiting the progress of information technology. Obviously these factors are not completely independent of the topics just discussed. Resistances or inhibiting factors can be viewed as organizational impacts just as surely as any of the others. There are, however, good reasons for treating these factors separately.

As is true probably in every other company engaged in electronic data processing work, Jersey has experienced a number of frustrations in advancing the work. To use a crude analogy, it is like trying to force a highly viscous fluid through a fine screen: until we can generate enough heat to lower the viscosity, only an occasional drop penetrates. The following discussion represents an attempt to analyze some of these resistances, with no intended order of significance.

COMPUTERS IN LIMBO

It is safe to say that our computers and most of their applications are not yet integral parts of the company's operations. Undoubtedly this is because of their novelty and the state of the art, but the present situation is one where data processing is held at arm's length, constantly being weighed, measured, and tested. This generalization, like all others, may not stand up under close scrutiny; but it is my observation that data processing has not yet been moved into the heart of the organization, where it must be to realize its full potential. Many of the applications which have been developed are the kind which an operating department found relatively separable without disturbing their other efforts. Payroll, for example, is a nice neat package which can be picked up and mechanized without much trouble, and hence we usually find it among the first applications. It is true that we are making headway in bringing the computer into active operations, but the tendency is for managers to consider the data-processing facility as an afterthought, if at all, rather than as an integral part of operations.

Another facet of this problem is the number and frequency of justification studies which computer installations must make. In the process of holding electronic data processing out at arm's length, management is still—rightly so, perhaps—asking to be shown how these expensive machines pay for themselves. However, this dissipates the energies of some of our most imaginative personnel and exerts considerable pressure to focus efforts on projects which can show the quickest and most obvious payouts. Yet it is conceivable that the projects which would make the greatest long-range contributions are the very ones for which justification is most difficult, and hence we tend to lay them aside for another day.

It may well be that this is an evolving process and that time will place electronic data processing in its most productive place. There is need, however, for us to recognize the ultimate objectives so that we do not lose sight of opportunities to progress in the desired direction. There is a danger inherent in all such delaying actions—the danger that our computer men will learn to be complacent about their role and fail to push deeper and deeper into the vital operations of the company.

Computers Make Haste Slowly

There is an old familiar story about the country agent who was pressing a farmer to employ modern agricultural practices. The farmer's reply is most appropriate in the present context: "I already know how to farm much better than I am doing."

In the same way, many of our computer men know how to build much better systems than they are now building. We know how to fly but we are still walking. There are many reasons for this, not the least of which is the ragged front presented by our electronic data processing units. In most cases, they are manned by people at all levels of training and sophistication. Thus, since most applications involve a team approach, the lowest common denominator is sought. In addition, the development of a highly sophisticated program will create difficulties (it is said) when it is placed in operation beside more pedestrian programs. In other words, limitations in personnel slow the steady progress toward more efficient programing. It is as though we were faced with a severe step function or a long series of plateaus from which we could move upward only by simultaneously upgrading the efficiency and power of all existing programs.

Client relations are another cause for failing to act as intelligently as we know how. As a general rule, the more efficient and sophisticated the program, the more sweeping it becomes in terms of change in the ongoing system. Data origination, flow, and utilization may change drastically, requiring a co-ordinated shift of operations. And such changes will not be possible until management and employees of the organizations in question have become fully aware of the characteristics of the new system and the wisdom of the change.

The point of all this is that computer technology is progressing far more rapidly than application. For several reasons, we are not utilizing to their fullest the skills we have developed in this field, and once again there is need to guard against a regressive tendency in our people, lest we step into the ruts of low-powered applications. One of the ruts into which we have stepped is the tendency to develop highly specific programs or systems which lack the power of generalization. They fill needs by duplicating in machine systems the contents of existing manual systems, but they fail to capitalize on the opportunity to move to greater efficiency. Highly specific programs tend to be somewhat inflexible and expensive to modify. We have had several cases recently in which unfavorable client reactions have developed because of the inability or unwillingness of computer personnel to make fairly simple changes on short notice. It is true that clients must be dissuaded from making abrupt changes without taking into account the reprograming required; but flexibility of operation and change must be of vital concern in our systems development. In any company, rapid change is inevitable, and our systems must be realistically flexible if they are to survive. This is particularly true in the early days of an operating system when, as I shall mention in a moment, client departments still regard the new system with suspicion and perhaps latent hostility.

To return briefly to the subject of generalization, it is my contention that we should be devoting more attention to the study of basic parameters of information systems. We should be attempting to define a rather limited set of dimensions within which all or most data systems can be described. This view is based on the assumption that all data systems have certain characteristics in common and that once we have constituted a set of general dimensions, any system can be operated from a highly generalized program. In one sense, the current efforts to develop automatic programing techniques are operating against this objective by making it too easy for us to develop specific programs with limited generality.

Suspicion, Hostility, and Subconscious Sabotage

Resistance to change exists as a universal phenomenon in organizations, and its presence is felt strongly in every phase of information technology. We should not be surprised to find suspicion and/or open hostility greeting the introduction of computers in an organization. Consider, for example, the reactions of a manager or a supervisor who is told after some study that the work of his thirty or fifty clerks can be done by perhaps ten people working with a computer. Perhaps he has been striving mightily to get the job done with only his present staff; and we tell him he will need only a fraction of that staff when the programing is completed. Even assuming that none of our people has selfish motivations to build and maintain an empire, it is rather deflating to a person to hear such claims, particularly if that person has little knowledge of computer power. Is it any wonder then that we meet resistance?

There are, to be sure, good and poor ways of interacting with potential clients in systems work, but it is not my intention to make this a "how to do it" paper. Rather, I merely wish to state that resistances are inevitable and we will be well advised to govern our behavior in accordance with this knowledge.

Some of our greatest problems in operating large-scale systems exist at the point of data origination. The data flow stops or becomes erratic, errors occur at disturbing rates—these types of problems continually plague systems people. And I contend that these are symptoms of the basic resistance on the part of client employees. It would probably be impossible to trace such problems to deliberate sabotage, but most data systems are extremely vulnerable to what may be called subconscious sabotage. Clerks engaged in preparing forms for transmission of data to a computer system may, because they feel threatened by the system, resent the innovation, or for any number of similar reasons, introduce errors without conscious effort. It is almost as if they were saying, subconsciously, "You're so smart, Mr. Computer, let's see what you can do with this," as they record a non-valid digit or incorrect codes. On a higher level, clients may be engaged in this game when they introduce at the last minute a change which cannot possibly be made before a scheduled computer run. Nor, indeed, could it have been made in the manual system which existed before the computer program was built, despite claims to the contrary. In short, computer systems are constantly being tested in this way, and when they respond as they must, there is a comforting "ahah!" reaction in the innermost recesses of a resistant client: "Computers, too, are fallible."

Thus far in this topic we have been dealing exclusively with electronic data processing and computers, but many of the same reactions exist in operations research or applied mathematics. Someone has said that far less than half of the completed studies in operations research ever see operational application. The techniques are too complicated for a practical businessman to follow, the answers do not square with common sense, or the mathematician's "deliberate oversimplification" has distorted the realities of the problem. All these and similar issues give rise to resistance on the part of clients.

All of this is intended to justify the assertion that information technology will proceed slowly or rapidly, depending on our skills in engineering social change. Technical skills in system development are crucial; but the most efficient system ever designed is capable of failure if we fail to take intelligent action in overcoming the inevitable resistance to it.

In short, there are many forces operating within an industrial organization which serve to impede the progress of information technology. Not all of these forces have been described in this paper, but we have suggested several which appear important. Some of them stem from the relative lack of resiliency which exists in any organization of human beings. Maintenance of the status quo is one facet of this problem, but resistance to change involves other things, like threats to personal security and ego structure, uncertainty about the wisdom of mechanization, etc. It seems clear that the computer and electronic data processing are regarded as mixed blessings and, as such, our staff people in these functions are forced to a defensive position where they must justify their existence continually.

I have suggested that resistance to change is perhaps the most significant barrier to the development and installation of increasingly sophisticated systems. While some of this resistance stems from emotional responses, some occurs because of purely intellectual problems. Systems work and particularly complex computer programs necessarily involve ways of thinking which are different from those familiar to most people. The requirement for clear, consistent logic, the use of abstract generalizations, the language of the programer, the introduction of mathematical concepts such as matrix algebra or set theory, and the rigorous requirements of data codes and classifications—all represent skills and knowledges not present in the typical business executive. To overcome this informational barrier requires painstaking explanation and education at every step; the total impact of these impediments can only be dissipated when these complicated skills are spread throughout the organization.

FUTURE IMPLICATIONS OF INFORMATION TECHNOLOGY

Much has been written on this topic and, because it must be highly speculative in nature, I shall give it brief treatment, leaving a more complete exploration for the Seminar meeting. I shall confine my discussion to speculations about my own company, but there seems little doubt about the generalization of these developments in other companies.

ORGANIZATION

It seems clear, as I said earlier, that decentralization as we know it will be under severe scrutiny in the future. In large organizations, decentralization evolved as a principle chiefly because of size and complexity. It probably has no real virtues in and of itself, but it has been successful primarily because it permitted tasks to be divided into manageable chunks. Now we are saying that what was formerly impossible because of size can be done on a centralized basis. Since this removes the original motivation for decentralization, why should it continue? Obviously the answer is not so simple, particularly since decentralization has become institutionalized and thus will create some pressures for its retention.

Some change in the direction of centralization must await technological improvements, like data-transmission facilities, but we already have examples of the use of a central computer which operates upon data fed through leased lines. The payroll for the Carter refinery in Billings, Montana is computed and transmitted from Tulsa, Oklahoma. Technical computing from Baton Rouge, Louisiana is done on a 704 located in Linden, New Jersey. These are just two examples of the use of a central computer for far-flung operations, but they serve to illustrate the nature of things to come. The efficiency of a computer's operation increases with volume, and this fact alone will exert pressure for central processing of data. This is not sufficient, obviously, to destroy decentralization, but it is one of the factors which prompt the prediction that the centrifugal forces of the past twenty years will reverse and become centripetal.

MANAGEMENT

The management process will always be with us, but the future promises profound changes in the way managers develop, the skills they possess, the methods they employ, and the composition of their ranks. Decision-making will cease to be the exclusive property of the manager as we learn to utilize the computer for certain of its aspects. As certain echelons of management diminish, the role of the staff specialist will change. There is some doubt today as to whether electronic data processing units will remain as staff units or become, in effect, line organizations processing in direct fashion the operational data now the property of line units. It may well be that the information specialists will occupy a central position between operating units and the top management whom they serve directly. At any rate it seems clear that the status of electronic data processing units will change in the direction of greater prominence and influence.

It remains to be seen how we are going to overcome the problem of providing top-level managers with relevant experience. If we assume that they must have extensive experience with operations at several levels in the organization, how are we going to provide this experience if the ranks of middle management are diminished? We have said that future managers must have some facility in information technology—indeed, they must be programmers at a very high level of sophistication—but there are many problems connected with acquiring these skills. In short, the safest prediction we can make is that the management function will undergo profound changes or mutations, most of them in the direction of increasing the personal requirements of the manager.

Characteristics of the Work Force

Much has been written about predicted changes caused by information technology. It seems clear that in administrative organizations there will remain a number of fairly low-level positions, particularly those which involve origination of data. Information specialists will include several types of "data sanitizers" with the prime function of preparing data for processing within a central system. Today these occupations include the transcription clerk and the key-punch operator, among others. Even here, however, there is reason to believe that these functions can be performed in other ways, chiefly by technological improvements in data-sensing equipment. In short, although we can anticipate large changes in clerical work forces, the rapid changes in technology force us to make the somewhat useless statement that although we expect many changes we still do not know their precise nature.

SUMMARY

In this paper I have attempted to describe certain facets of information technology in our company. It is clear that Jersey Standard is very much in the business, with active work in progress on a number of fronts. There is no reason to assume that we have made more progress, met more obstacles, or experienced greater impact than any other company. Suffice it to say that more and more specialists and managers are becoming directly involved in some phase of the work, and others (a smaller number) are becoming aware of the organizational implications which accompany full exploitation of its potential. It is hoped that these numbers, particularly in the latter category, will swell as information technology achieves greater maturity and becomes a more integral part of our company's operations.

DISCUSSION

SHULTZ: Can you see any evidence of "learning" by transferring programs from one computer at one refinery to another computer at another refinery, in line with the forecast made by Simon in his remarks?

GROSZ: The generalized report system which I mentioned is used widely and directly with no alterations by a number of our companies. We have also given it to Guide [IBM-user organization]; I believe that there are other companies using it. It can be used by anyone who has a machine that can handle it. But as far as other systems are concerned, we have found that the only way that we can develop these so that several groups can use them is to have them developed. We have recently been able to develop a jointly used payroll system after an extensive series of conferences among the users. When these conferences began, there appeared to be unresolvable differences among the users, but it finally developed that there were really no differences at all.

SIMON: Has your understanding of how to build systems—not the actual systems themselves—been of help to you in developing systems at other refineries, and if so, how?

GROSZ: Yes, there has been a great deal of information about systems development passing back and forth between refineries. As a matter of fact, the division I head in New York has developed a mechanism for doing this. We have taken steps to develop a programing manual which will be of help for all our affiliates. We have put our best skill into this manual. It is true that we can deal only with generalized areas, and if a special program is to be developed for one affiliate, it means conferences with personnel from that affiliate, before such a program can be developed. I must admit we haven't found a good answer to this problem yet. Certainly just passing along block diagrams is of no help at all.

Simon: How much smaller a development project did you have at the second refinery as compared with the first refinery?

Grosz: I can't recall clearly, but I would say that if we were doing the job all over in a new place today, it would take about half as long as it did the first time.

Hines: In General Electric, the systems analysis group used the experience gained in developing a system for the first plant to produce a universal program. This was then passed along to the various other manufacturing units. These other units invariably rejected this program in favor of some smaller one which they believed more suited to their own problems, at least as they saw them. It later became necessary for the central systems group to reinstitute a general program in all units in order to give the department the kind of flexibility needed in providing for production of wartime manufacturing (should it be necessary) and in coordinating inventories and production schedules at three different locations. Before we did this, we often found that one of our three plants might be scheduling production of a substantial number of units of some transformer equipment, while at the same time the other two would have, between them, a warehouse surplus on that same item.

Vogt: The differences in approach to systems development which have been illustrated by these comments from Standard Oil and General Electric representatives may reflect differences between industries as well as differences between the way the individual companies are organized. In our case at International Shoe Company, we faced a special problem brought about by some rapid changes within our industry which had in effect rendered the company's organization, as well as its procedures, obsolete. This problem put the company under great pressure to move rapidly in all areas. Because of this, our systems group had considerable authority and latitude for doing their work. I gather that

Hines also had substantially more latitude in his operations than the Standard Oil people did. [To Grosz] Did you develop standard conventions for all of your installations in your various affiliates or did you permit each affiliate to use its own programing conventions?

GROSZ: We have developed a general programing framework which is used for all our IBM 700 series installations. You usually find out that your program is conditioned by characteristics of the equipment you are using as well as by the characteristics of the system you are working with. This means that you have an incentive to standardize programing conventions because of the use of similar equipment by different operating units.

ORDEN: In looking over the systems which you have installed in Standard Oil, do you find that the role of people is being further reduced as your systems development work proceeds?

GROSZ: I can give you one example. In the description of our payroll and personnel system at Baton Rouge, you will remember that we asked the foremen to make the allocation of men to jobs. We considered the possibility of transferring this allocation procedure into the computer as another step. We would seek thereby to optimize the allocation of men, based upon the priority of jobs, the backlog of jobs, and the skills available to tackle these jobs. Here is where we would alter the skill required of the foreman, skill used in making these allocations decisions.

ALBERTS: In the work you have done so far in the refineries and elsewhere, to what extent do you find that you are really evolving totally new systems rather than simply improving old ones?

GROSZ: The personnel system which I described would be simply impractical if we attempted to do it manually, or even on any previously known equipment. In installing such a totally new system, a real problem comes up as to whether you change the organization first or put the new system in first. In the case of our personnel system, the operating people at the refinery wanted the new system to go in before the organizational change was carried out. This created some problems.

SHULTZ: When you get a new system like this and make the organizational change so that you can now do things between ten and two o'clock that would formerly require weeks, what happens if the system breaks down? What do you do to provide some sort of backstop for this?

GROSZ: This is an important problem, and one which has slowed us down on development of our sales and shipping systems. You have to provide some sort of backstop system on an emergency basis. When you have bills of lading sent out and freight cars must be moved out of yards, if your computerized system breaks down you simply have to call in very large numbers of people on some emergency basis to get the cars out. Actually this sort of problem very seldom occurs.

VOGT: We have had the same experience. Our breakdowns have been most infrequent and have not been disastrous in any way. Our longest machine breakdown has been about four hours.

ORDEN: This problem is being dealt with to some extent by introducing flexibility into the latest machines. For example, interchangeable components make it possible to use one part of the memory while repairing another, to print out from several different tape sources, and even to have duplicated controls.

HINES: Our way of dealing with this breakdown problem has been to save earlier programs we had written which had been developed for lesser equipment [of the IBM 400 series]. If the new equipment breaks down we can shift to some lesser programs that we have in our library.

GROSZ: However, if you have developed a program which involves rules administration you cannot use the 400 or 600 series machines any longer. There are too many logical decisions involved, too many conditional transfers developed in these programs to permit use of a substitute program.

WHISLER: This is an important point. In developing these higher level programs certain kinds of hardware may become obsolete. In fact, it is possible to broaden the statement more. Recalling Grosz's comments on the developments of his personnel and payroll system, we could say that by incorporating sufficient conditional transfers into a program it becomes impossible to depend either upon manual operation or upon more primitive machines to handle the system. Developments of this kind may be at once irreversible and discontinuous. Gradual, cautious, probing changes of small parts of a system seem to be out of the question. We move in big jumps to new sets of organizational arrangements with little chance of partial retreat. Former ways of doing things cannot be regarded as readily available alternatives once the commitment has been made.

VOGT: We have used two gimmicks in trying to cope with this problem of reliability of the systems. One is to set up a farming-out agreement with another company which has equipment similar to ours, in case we have serious equipment failures. In addition to that, we hold our programs in storage, even though they have been superseded by others on an evolutionary basis, for at least two cycles. In one case because of operator error we were forced to, and were in a position to, redevelop our program this way. We also separate tapes and equipment in case of fire or other disaster so that we don't lose everything.

GROSZ: The problem of reliability bothers everyone in the organization. In putting in our stores system we ran into a situation where some of the personnel in the stores organization did not trust the system. They were entering manual orders—permitted in this system—on the basis of their own personal observations of the status of inventories, not trusting the system to have ordered already the materials in question. As a consequence, we had some substantial piling up of inventories until these people finally developed some faith in the new system.

As these systems are installed and function and perform their job correctly and efficiently, a momentum is built up for further development. The effects on the organization of drawing together formerly separate units, which Rush told you about and which Vogt mentioned, become irresistible. The walls of departments really do crumble. Once you have changed the system, people simply can't resist doing what then appears to be logical in an organizational sense.

ALBERTS: I think that in all of this talk about departmental walls' crumbling we had better be careful. We certainly don't mean that everyone is going to wind up reporting to the president. You must still retain an administrative organization down the line. The structure will still be there in some form. You may regroup and retitle departments, but they will continue to exist.

SHULTZ: I get the impression that there are two kinds of things happening here. On the one hand, you have some tasks that are pulled completely into the system and disappear entirely as a separate job. On the other hand, you have tasks that disappear only in part. An example of this would be the purchasing function which consists largely of statistical processing work, but also involves selection of vendors. You may take the statistical work away completely and leave the man with only a piece of his former job. He may take on more of this remaining work, with fewer people now involved in the function, or this part of the work may be expanded in various ways. But, whatever is done, the task content is changed fairly drastically.

GROSZ: Our buyers would agree with you. They believe their work now is much more analytical in nature. Formerly they were too busy with statistical work to get very analytical.

VOGT: It seems to me that this all relates to some comments made in some of the papers about the effects on middle management. I think the trend is to take away statistical and record-keeping work from people in middle management jobs, such as purchasing, and to leave them with what is really the essence of their management tasks. They used to spend a lot of time in record keeping and supervision of large clerical staffs, but that part of the job has disappeared. We would expect, consequently, a reduction in force, and that the skills of those remaining would increase.

ORDEN: I'm not quite sure what your analysis implies. What you call "clerical" work involves many choices and I'm sure that those people who are doing this kind of work feel that at least part of it involved the use of intelligence and reasoning.

VOGT: Perhaps I should have said that there is this purely clerical kind of thing—simply writing down numbers or typing material on paper—but that there is a higher level choice-making task, and that both of these have been largely transferred into the computer. We have left the purchasing agent with the job of vendor selection.

HINES: We have taken about sixty per cent of the purchasing agent's job out and put it into the computer and left about forty per cent. This forty per cent is largely vendor selection.

ORDEN: But the reason you have to leave this selection with him is that the computer is not mobile. What the purchasing agent is doing is largely going around collecting information about vendors.

HINES: The computer has changed our method of soliciting bids, too. We do this on a much broader basis than formerly. The agent still solicits bids, but he does this by broad commodity classes rather than on pieces of the vendor's line. We are able to get better prices than formerly, and the ability to do this is largely due to the speed of the computer in furnishing the purchasing agent with specifications on an entire commodity class before he solicits bids.

[*Editors' note: The purchasing agent that Hines is discussing is different from the buyer which Vogt is discussing. The purchasing agent generally buys in terms of some specified set of needed inputs into the manufacturing system. On the other hand, the buyers whom Vogt discusses are also merchandising people, similar to buyers in retail stores. They are trying to buy what they believe will sell and thus have responsibility for market analysis, inventory levels, and other problems. The buyer's job probably would be regarded as a more complex one than that of the purchasing agent.*]

HUNTER: I think it is important to note that if, as Hines says, the computer is being used to evaluate the performance of suppliers in terms of quality and delivery, then the purchasing agent is really not making decisions about vendors himself but is getting this information from the computer.

ALBERTS: Some of the difference in the way we evaluate the effects upon jobs may arise out of the fact that we come from organizations which have had different sets of experiences of prior systematization. What happens to the organization when information technology appears depends upon the state of the organization at the time it appears.

WHISLER: This point is well taken. The Seminar illustrates the difficulties attendant upon generalizing from small samples. The Seminar participants were deliberately chosen because of the variety of experience and background that they represented. As a result, in discussing some of these matters we get differences of opinion based upon the very differences that we had sought. In looking over the comments and considering the nature of the developments in various companies, it seems reasonable to state that, in general, an organization which has been constantly subjected to a rationalizing process through the years will change less under the impact of information technology than will one which has been highly decentralized and sort of run by the seats of various people's pants.

SIMON: Referring to the problem of personal satisfaction on the job, or happiness on the job, it is one thing to identify changes in job content but quite another to make statements about what happens to the satisfaction of the job holder when these changes occur. A man who has been pushing paper around, making lots of 'phone calls, and placing orders may be happy feeling that he is accomplishing a great deal and never be concerned about his autonomy, and such matters. What I wish we had here is some way of measuring and comparing these two things—job content and job satisfaction.

ALBERTS: Most management men feel that they are not really filling the specifications of their jobs in terms of the most important activities of the job, because they are burdened with an excessive amount of detail. By putting the routine part of their job into the computer we may give them time really to do the sorts of things that they should do as managers.

MCGREGOR: I quite agree with Simon. We could sit here and say that people will now be making decisions and be finding themselves happier, when they may well be finding themselves unhappier.

Rush: However we may measure the importance of the content of a managerial job, we must reckon with the fact that many people measure it in terms of the number of people supervised. Very often, in some organizations at least, the individual's compensation is at least in part related to the number of people he supervises. As information technology moves in it may well be that we would, as outsiders, assume a man's job to be increasing in importance and richness of content, while at the same time the number of people he supervises may diminish radically. We will have to watch this problem and see that our ideas on status and compensation aren't dominated completely by the measure of the number of subordinates one has.

Grosz: In noting Rush's earlier comments on decentralization, I think it should be clear that in our corporation we have always had a need for a substantial degree of co-ordination. If we had had no co-ordination, we would have long ago found ourselves competing with ourselves in a completely wasteful manner.

Rush: That's true. There may have been a number of forces which have been motivating our company to emphasize the importance of this co-ordination. I think it would be a mistake to go too far in assuming that any changes in the degree of decentralization in our company or any other could be attributed to the introduction of information technology. Such developments may be occurring, but for other good reasons, mainly economic ones.

Whisler: However, even if you can point out some other reasons for centralization in a particular company, we may still have reason to believe that information technology has a centralizing bias if its introduction is almost always accompanied by integration and centralization of decision-making.

Simon: It's certainly true that there was very little talk about centralization until the computer raised its ugly head. We know that there are trends back and forth in thinking about things like centralization, but I saw no evidence that the tide of sentiment in favor of decentralization had reached its high point until the computer came along. I think we should be cautious about cause and effect here, but I think that, at least at the verbal level, the computer provided a reason for much more talk about centralization.

HUNTER: I think there had been considerable talk which was critical of decentralization even before the computer came along. We learned that it is necessary to co-ordinate product policies and price policies, and that division vice presidents must establish their own operating policies in terms compatible and consistent with other divisions.

HINES: We had already done some substantial centralization of service functions for reasons other than our ability to process information more efficiently.

ALBERTS: I believe it's true, as someone else has mentioned, that one of the strong incentives for decentralization has been the inability of large companies to solve their communications problems inside. I think there's no question but that the computer helps in this problem.

GROSZ: Certainly, if you can use a tool like the computer to control and co-ordinate centrally your inventories, even though they are spread throughout the country or the world, you should go ahead and institute such central control.

ALBERTS: This is beautifully illustrated in the case of the Bureau of Aeronautics (U.S. Navy), where the inventory system is controlled on a worldwide basis.

SIMON: I think, however, that the place where this arm's-length kind of organization which we call decentralization gets you in trouble most often is not in the area of co-ordinating dispersed inventory centers but in relating manufacturing operations to your inventory situation. Very often the inventories become a catch basin necessary because of poor co-ordination between producing and distributing. So even if your warehouses are widely dispersed it may be quite desirable to co-ordinate and control centrally as a means of minimizing inventories.

SHULTZ: One thing our discussion illustrates is the importance of distinguishing between the centralization of planning and the centralization of operations. These need not always move in the same direction.

RUSH: I would like to bring out another problem that I emphasized in my paper. Our company has always encouraged a lifetime career orientation toward employment in the company. As information technology has moved in and had displacement effects of a substantial nature, our personnel planning people have had to look very hard at the kinds of people we are bringing in. At the refineries, for example, we have not been hiring for years. We have been following a program of "attriting out." As a consequence, our average age is rising rapidly there—at the rate of about 0.8 years per year. This kind of situation puts new emphasis on the importance of selecting people in terms of their skills and personality.

SHULTZ: It also raises some questions about the wisdom of emphasizing lifetime career orientations.

GROSZ: One of the persistent problems which Rush has mentioned is that of resistance to the changes brought about by computers. We have found that where the systems have been in for a substantial period of time much of this resistance disappears.

SHULTZ: Doesn't the information about successful installations at one place help you out when you move into another place for a new installation? I would think that there would be some interplant and interdepartmental competition on this score.

HINES: We have found by and large that we have to sell ourselves all over again when we move into a new area. Our experience has been that each local group regards its problem as unique and attaches little value to the experience the staff group has gained in previous work.

VOGT: We have had, in at least one instance, almost the opposite experience. We had such a successful installation in one factory, measured in terms of reduction of inventories of goods in process and in manufacturing time, that the experience became a legend in the company. Other superintendents were demanding similar treatment of their factories right away. We suffered considerable criticism, since we could not always meet their demand when they made it.

GROSZ: One important point we have found in our experience: Where we are making a computer installation, if we have a top management committee simultaneously insisting upon improvements and innovations, we can't make the changes fast enough. This is the single greatest aid you can have.

ATWOOD: I have been very much interested in listening to the discussion about the problems of acceptance which apparently all of you have had in varying degrees. We have not had too much trouble in our company. I believe that the reasons for this are: (1) that a small company can communicate its objectives easily and quickly; (2) that our program of installation of the computer has had the complete support from the top; (3) that the caliber of the man who was responsible for installation of our program was very high; and (4) probably most important, that our company has always had a philosophy that considers change to be normal and healthy.

THE ATWOOD VACUUM MACHINE COMPANY

By

Seth G. Atwood[*]

The main offices of the Atwood Vacuum Machine Company are located in Rockford, Illinois, and at this plant we employ between 1000 and 1200 people. A second plant, approximately fifty miles away in Stockton, Illinois, employs between 300 and 350 people.

A computer type of mechanism is employed for various purposes that will be described later relating to these two plants. The three other plants of this corporation do not at present utilize a computer.

At the two plants under consideration in this paper, approximately seventy-five per cent of the total sales volume is comprised of automotive internal body hardware which is sold as original equipment. By "internal body hardware," we mean such items as seat adjusters, door hinges, hood hinges, door locks, deck hinges, hood latches, and other mechanisms of this kind. The remaining sales volume consists of trailer products like jacks and couplers, bicycle products or parts, and coin handling, bottle vending, and cup dispensing mechanisms, including paper money handling devices for the vending machine industry primarily, although these products are also used in laundromats, super markets, amusement parks, and other places.

A breakdown of the sales would indicate that we shipped approximately 2000 finished parts and assemblies. We have in process approximately 10,000 different fabricated parts made from 500 different types of raw material, and purchase approximately 5000 parts from the outside.

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[*] President, Atwood Vacuum Machine Company.

EVOLUTION OF DATA PROCESSING

Because of the highly competitive nature of the bulk of our sales, namely, to the automotive industry, and their stringent and varying requirements with regard to manufacture and delivery, this company was and has been acutely conscious for a long time of the need for flexible, simple, up-to-date, and accurate methods, with low cost in paper work procedures. By 1946, this company had and used a rather complete IBM punch-card batch system for handling masses of data such as inventory, payroll, production requirements, purchasing requirements, cost accounting, and sales forecasting.

We, as most companies, were intrigued with computers when they were first announced and began to be used, and did some preliminary study to determine whether they might be used, by an organization of our type and with our problems, to any advantage. It seemed to us, and it still seems to us, that the computational type of computer could not and cannot be used economically by our organization. It was our good fortune, however, to learn of the activities of IBM in the area of random access accounting and control. We happened to be one of the first companies to place a RAMAC on order with IBM in the middle of 1956. This machine was delivered over a year ago.

PREPARATION AND ORGANIZATION FOR RAMAC

Prior to the receipt of RAMAC, it was clear that paper work in the office stems from three primary sources—research, sales forecasts, and customer instructions regarding product quantities, delivery dates, engineering changes, etc. With an IBM punch-card batch installation used for the various purposes indicated previously, it was clear to us before introducing RAMAC that paper work functions performed cut across many divisions of the company, particularly Accounting, Manufacturing, Purchasing and Engineering. For this reason, in the early 1950's we established a Planning Division, which was on a level with the other divisions mentioned and essentially might be thought of as a paper work clearing house. With this type of organizational structure, we did not need to burden Purchasing with decisions of about how much to buy and when to buy. That division was left free to determine from whom to buy and at what price. Similarly, in the case of Manufacturing, they did not need to concern themselves with how many products were required or when they were required.

We placed an order for RAMAC without making any detailed study of feasibility or application. The theory of the machine's operation in itself enabled top management to conclude that the unit would be adaptable and useful for our purposes. Because of the random access feature in this equipment, it was obvious that paper work could be performed on an in-line daily basis instead of a batch sorting method, and that therefore all information that we needed would be continuously up-to-date. This, of course, is the key factor; and the implications of this statement, as it relates to all of the activities which we try to do, are very far-reaching indeed. It takes only a moment to realize that we have stored in the machine all bills of materials, all inventory information, all purchase order information, all shipment information, all sales forecast and customer requirement information, all price information, and all cost information relating to production of a given piece broken down by operations; and that through random access, we can arrange this information in any form which we find suitable or desirable for us, for purposes of running our business as it relates to these facts. Most importantly, however, these facts are more or less immediately available and all of the information is at all times completely up-to-date. For example, when we make one shipment of a product, that shipment will on the average affect thirty-three records in the RAMAC storage unit. The time saving and availability of information for decision-making under a system of this kind was, of course, completely obvious. As a corollary, it was also completely obvious that we could question the machine for information and receive the answer in writing and in minutes, whereas processing on a batch basis for certain inquiries would not be economically justified.

A second important feature in the over-all decision related to the fact that we could boil down the mass of paper involved in batch processing to a system of exception programing whereby the machine simply passed over all items in balance, or, meeting certain requirements, brought forward to the attention of personnel only those items which required attention.

The third feature was the fact that we could do much more work faster and almost eliminate peak loads, because of the in-line processing feature.

On the basis of these general facts, management decided to purchase the machine and to leave it up to the Planning Division to work out the detailed programs and to decide what records we wanted to maintain, how they should be stored, what information was essential, and all the rest of the processing details. Approximately four months prior to receipt of the machine, two employees were freed to work out these details. They attended a programing school and learned how to talk to the machine and draw up flow charts showing the procedure to be followed on each transaction. During this period, we found that we had to make changes in our records; by the time the machine arrived, we were in a position to utilize it immediately. The transfer of operations to RAMAC was scheduled and, much to our surprise, we found it useless to parallel records for more than a few days or two weeks at the most.

WHAT WE DO WITH THE COMPUTER

Previously, I stated the types of information that were stored in the machine. Obviously, at any time we can utilize this information, in any combination or manner that we feel appropriate, in order to make a decision. Some of the reports which we obtain from the machine are made on a regular basis, and there are many inquiries which are reported intermittently as the need arises. I think we would gain nothing by describing in detail all of the columnar headings of the various reports to you. Suffice it to say that regularly we develop sales forecasts, and, on a daily basis through the exception procedure, find out what is required to be done from the manufacturing and inventory control points of view (which, of course, include purchasing) as a result of transactions that have taken place, such as shipments and incoming orders in relation to forecast, minimum order quantities, economical production run quantities, etc. Engineering changes are handled on a daily basis and updating of all records is performed routinely. It is obvious that, as a result of an engineering change, a number of other wheels may be set in motion—cancellation charges to the customer, changes in purchase orders to suppliers, product cut-off dates established, etc. Speaking broadly, sales information material and production control activities, since they affect so many records, require approximately six hours a day. Other items or general areas processed on a regular basis include payroll and cost accounting, and we are at the moment trying to find time to put on billing.

On an intermittent basis, there are many things which we can and do do, because of the flexibility of the equipment. Many of these things could not be economically done—and in some cases are not even feasible—under a batch card system. For example, when the steel industry raises prices, the automotive firms demand a detailed breakdown of these price increases as they affect the product sold to them; and it is possible for us to prepare this report, in terms of inventory on hand, inventory to be received at the new price, and its effect on every single detail part of each assembly, almost immediately after we receive notification of the amount of such increase.

It is apparent that the machine is very valuable to us in estimating. We can query the machine about detailed operational material cost on any part or assembly for purposes of estimating new jobs, or for purposes of comparing actual costs against estimated costs for current work being done. We can furnish our customers with accurate information on the status of orders, particularly as this may relate to their inquiries about obsolescence charges as a result of proposed engineering changes, and the most desirable cut-off date for making a change. We can query the machine about labor requirements by type of activity and capital equipment requirements based upon machine utilization and load centers. We can draw off reports of sales analysis by product classification, by customer, by region, etc. With all this data recorded and the random access feature, top management's job and middle management's job have been that of becoming gradually aware of the facts available for decision-making.

Results

By now it should be clear to the reader that the results of this new piece of office equipment have been extremely gratifying to us. We have been surprised at the efficiency, speed, and reliability of the machine. It has increased our accuracy in terms of factual information, and has required an increase in the accuracy of reporting information to a marked degree over what we felt we had built into the batch system. There are two reasons for this. First, changes are made on a daily basis; and if there is an error somewhere because of the fact that we are operating on an exception method in this equipment, the exception card keeps coming out of the machine until someone takes care of the problem involved. Past practice in control produced voluminous and insufficiently adaptable records. As many of our transactions affect assemblies rather than parts, in the past it was necessary to break down all of these assemblies into their component details, and then break the parts down into the raw material from which they were fabricated. This involved handling numerous decks of cards and bills of materials; and then these decks related to assemblies forecast, shipped, released for production, etc., which created a large card volume. It was therefore not reasonable to explode all of this detail on a daily basis. Even if we could have prepared these reports, inventory, manufacturing, and purchasing clerks would have been swamped with paper. Under a batch system, we had to be satisfied with updating our papers once a week, once every two weeks, or even once a month; and accordingly, whenever a transaction occurred in the middle of a period, all the other records affected were either old or new and, of course, this resulted in an erroneous record. The second point is that all of these erroneous records were immediately highlighted by the RAMAC operation, and in the same manner that our office procedures and record keeping had to be brought up-to-date and overhauled when we first introduced bills of materials and punch cards for batch purposes, we found ourselves again refining and improving our accuracy in order to operate with RAMAC.

I would like to make a comment or two about how top management looks at the economics of this unit. First of all, we can say that the unit is worth more than the rental paid. The actual out-of-pocket costs are approximately $1000 higher per month than they were under the batch card system. We were able to release a good deal of standard batch processing IBM equipment and effect some small reduction in payroll. The reason, however, that we say it has more than paid for itself is that we would hate to have to pay for the information which we now receive, if we had to do it by some other method. More important, this information is necessary. I am referring specifically to such things as the control of inventory. Savings in material control involves, of course, much more than keeping inventory at a minimum working level, although we have made substantial gains in this area (approximately thirty per cent reduction) because of the timeliness of the information. With respect to our product relationship to automobiles, we are now in a position to control inventory efficiently, relating it to schedule changes, engineering changes, and the tremendous problems involved annually when there are model changes. The timeliness of the information, from a manufacturing and control point of view, is worth a great deal of money and at the same time enables us to give our customer much better service. The improved accuracy of both our records and our equipment is of significant monetary value.

The fact that this equipment lends itself to processing all transactions on an identical basis is important, in that it permits a standardization of procedures. Under a batch method, it was necessary to adopt a number of different procedures, depending upon the economic value of the transactions under consideration. The machine has forced a tightening in individual performance, in the sense that erratic, unreliable actions or mistakes by people are highlighted through exception procedures. Under the batch method, because of time lag and the fact that both good and bad conditions were reported, there were excuses for resultant errors —which in many cases were nothing but personal errors. Finally, in turning to assess the value of the equipment, we must take into consideration the fact that the machine operates much more rapidly than our previous methods, and that the ability to program the unit especially for isolated bits of information involving correlating and assimilating a mass of facts has resulted in reports to management that make decisions simpler. The questions involved could have been asked—and probably were asked mentally—by management under other procedures, but it was quickly evident that the costs of obtaining the answer were not justified, in either terms of labor or of time.

The Results as They Relate to People

In our case, the mere fact that we went from batch punch cards to RAMAC has not resulted in a violent shift or change in our over-all method of operation. Weaknesses in certain areas have highlighted people's failures to perform necessary detail functions. At the outset, it was somewhat difficult for middle management to become accustomed to working from exception reports, as contrasted to complete machine read-out on a given subject.

For a considerable time, there has been no room in our organization for a salesman, engineer, or purchasing agent who wanted to keep his own records and run his own show. I think that RAMAC has simply accentuated this fact, in the sense that the fellow who does want to keep his own records is not being told what he has to know to do so. Only RAMAC has that information; therefore he is forced to go to RAMAC for it and, furthermore, to realize that he must give the necessary information to RAMAC in order to get results.

Frankly, there has been little personnel dislocation, partly because most of the change occurred within the Planning Division, where the paper work function was being accomplished in the first place. Attrition and increased volume of work took care of any problem relating to reduced personnel requirements. I think it would be fair to say that, rather than a negative attitude prevailing outside the Planning Division, a positive attitude prevails as a result of the fact that better and more accurate information is available. A more important positive point is that one might say that management is becoming more information oriented, in that we now realize we can call upon RAMAC for certain information that in the past would have involved unreasonable effort.

One of the more interesting results of RAMAC was a feeling of pride on the part of personnel because the company had a RAMAC. When a customer asked difficult questions about status or the effect of an engineering change, a salesman enjoyed telling him that he could have the answer in fifteen minutes. Even the people in the plant rather enjoyed, I suspect, going home and telling their wives about all the lights flashing on and off. Fortunately, some of our visitors have been our customers; and Sales feels that RAMAC has been a real selling tool. This plus value, of course, is short lived. The activity of the planning unit gives concrete meaning to statements regarding aggressive corporate activities and reinforces the philosophy that change is normal and not an exception.

The whole attitude of open-mindedness and helpful co-operation toward improvement, in any and all areas, is the cornerstone of our employee productivity bonus participation plan, known as the Scanlon Plan. Indeed, it is highly probably that the Scanlon Plan materially simplified some of the personnel negativism that might have existed if people had not been previously oriented to an acceptance of change.

The computer took part in another interesting development occurring in this company. We had a manufacturing operation in Chicago which we decided to close out and move to Rockford in the late spring of 1958. Certainly one of the reasons that we made this decision was that we had a paper work organization structure and method of handling transactions in Rockford which we could not afford to duplicate in Chicago, and which was far superior to the method being used in the Chicago operation.

In the same way that paper work processing, since it cut across all other divisional activities, forced us long ago to establish a Planning Division, I suspect that Planning will become more important as it questions the machine on more nebulous problems, and that some of the arguments and reasons for decentralizing operations will be outweighed by the fact that, through centralized operations, more effective use can be made of proved efficient techniques resulting from computer applications. Certainly this is true in our case. It is clear that top management is becoming more computer oriented, although to date we have not had reason to utilize this equipment on any large special project problem-solving function. It may be that we have not been so alert as we should to recognize one of these special problems into which we might delve by setting up a model and taking a number of factors into account; but I am sure that in the future, as our business grows, we will have occasion to utilize the machine more and more for this type of project.

CONCLUSION

This paper was not intended to survey the field of computers in general, but simply to outline roughly a down-to-earth, practical application of a type of computer in a small organization. As you can see, we are not involved in staggering engineering problems which would make a computational type of computer desirable or necessary, because of the type of product we manufacture. We have looked into the computer, or computers in general, for purposes of controlling certain machining functions, including tool and die making, and have concluded at the present time that this would not be economically justified. Our studies indicate that a reasonably priced computer could be used for tool and die making. The break-even point here at present appears to be about $25,000.

In our organization, it is agreed that for our purposes this particular computer is an important office and management tool—that it is well worth the rental which we pay. Within six months, it will be running two shifts instead of one. The machine has materially improved decisions which we must make. New uses will become evident to us as time passes. At some future time, we will be using computers for controlling manufacturing processes directly. Finally, these changes can and will be made without any serious strain on people.

[*Comments made at the Seminar by Mr. Atwood as a supplement to his paper*]

After reading the papers and listening to the discussion in the Seminar, I have reached two conclusions. The first is that our company's mechanical problems in the information technology area are like those in the large companies represented in this Seminar, except that they occur on a miniature scale. Second, that, while we have the same mechanical problems that others do, I believe that we have been spared the personnel problems and the frustrations that have been expressed by a number of the other participants.

I think that our happy experience in the organizational acceptance of the computer has been due in large part to the fact that we conceived our application of information technology in terms of the company as a whole, right from the beginning. The impact of the computer on our company has been tremendous. But, because of our particular managerial philosophy, we have been able to avoid many of the problems, which seem fairly common in the large company, involving ways to gain acceptance of the computer and to make the necessary organizational adaptations.

I can illustrate what I mean by discussing what has happened to our organization. We are presently organized into six divisions: Manufacturing, Finance, Sales, Personnel, Purchasing, and Planning. With this divisional arrangement, we have eliminated the concept of staff people. We have been able to avoid the kinds of problems that the existence of staff creates by simply not having staff around.

Planning, then, in our company, is a line function. It was not always such. We once had all kinds of staff people, but we could see no reason for continuing to have the kinds of problems that staff people create. So we eliminated staff. We have simply taken all planning functions out of other divisions and put them into this one. For example, Planning determines how many of any given item shall be purchased and when it shall be delivered. The Purchasing agent is left with the problem of deciding from whom to buy and at what price. Similarly, Manufacturing does not decide how many items to make and when. These decisions are made by the Planning Division, and Manufacturing simply makes the items. The Planning people do not "sell" any other division on anything. They go ahead and decide what the job is that has to be done and how to do it. I think this lack of staff distinguishes our company from others participating in the Seminar.

We are essentially a sort of job shop. Our prime requirement is flexibility in procedures and organization. We have a continuous stream of engineering changes being introduced into our production methods. Our schedules are continuously changing at the whim of our customers. Each year seventy-five per cent of our product line is changed. As a consequence, we have a tremendous amount of detail to take care of, and we need a very well developed information system.

As I described in my paper, we felt that a RAMAC was best adapted to the size and operational requirement of our company. Incoming data relating to orders, shipping releases, engineering changes, and other matters, as well as data from our plant (engineering changes, etc.), are all fed into our Planning Division. These data go through no other divisions or departments, except for incidental inspection and information on such matters as prices. All these data, as well as information on inventories, shipments, and purchase orders, are fed into the RAMAC. Then the Planning Division, with all of this information spread out before it, simply programs the machine to get from it whatever is needed to run the business—bills of materials, schedules, and so forth.

I discussed in my paper some of the uses we make of our RAMAC. An additional one I might mention is that of computing product price changes necessary to recover an increase in steel prices. This has to be done for all the parts and products we produce, according to the weight and kind of steel in them. This, at one time, required a special report which took a considerable amount of time to prepare. It is now a very simple operation. We use the machine extensively for inquiry, particularly when we are trying to estimate in making a bid. For example, the machine will give us operational costs on every part involved in any product on which we might want to bid.

I think, though, that the key factor in savings that the machine has effected for us has been in the area of inventory control. The ability to reduce obsolescence losses and to establish, clearly, cut-off points on engineering changes, has resulted in some remarkable savings.

A number of the Seminar participants have expressed the belief that the accomplishments in their companies to date are small in comparison with the potentialities. I am not sure that that is true in our case. I do not mean that we have exhausted the possibilities of systems development in a company like ours, but I am inclined to think that the economics of information technology are different for the small firm. I think that when a company of our size installs an information system like ours, on an over-all basis it results in a tremendous initial competitive advantage. But I believe that this advantage is short lived. Other companies will adopt this same technology, and I think that subsequent growth is quite slow. We regard our decision to install the RAMAC as an important one, but perhaps no more important than some other management decisions we have made and will continue to make. By this, I mean decisions such as those to invest in product research, decisions about labor relations and human motivation, and decisions about improving marketing techniques.

Leonard Vogt pointed out that the extensive review and planning involved in setting up new systems very often has in itself significant and positive effects upon company organization. We have had the same experience. In our planning and thinking in connection with the installation of the RAMAC, we tightened the organization considerably and improved our accuracy in data input and in our thinking about information flows.

I believe that we avoided some of the problems others have had in getting people to use the new equipment simply because we gave them no alternative. If the equipment was not used, they got no information at all. We had no parallel system available. This, I think, resulted from our managerial decision to go all out in installing a comprehensive system and in putting it into a planning division.

It is my judgment that our people have reacted positively to the introduction of information technology. Our management people feel they now have the tools to do a better job of managing.

This, I think, is particularly true in our Production and our Purchasing functions, but it is also true in Sales and the Cost department. For the first time we feel that we have really good cost information. I agree with Vogt that we will probably find that we can give up having to rely upon standard cost systems and move toward using actual cost data.

We do not claim any magic secret of knowing how to introduce change while avoiding the problems usually associated with it. I think that any company can do just what we did, if those people on the payroll identify themselves with the company and with the company's philosophy. We have tried to do two things in our company to achieve this state of mind. First, we have sought to give individuals maximum freedom and maximum use of their own abilities at all times. In the second place, we have worked hard communicating the concept that change is normal in our company—it is the everyday state of affairs. When individuals are given freedom and the opportunity to use their own intelligence and skills, we believe that they will see that change serves their own goals and will become flexible in their behavior.

I would be remiss if I did not give the Scanlon Plan the importance it deserves in explaining our company. The Plan is based on the premise that people do not have to see things the same way or even have the same goals, provided that there is some way in which they can discuss the differences they have and reconcile them. It is based, secondly, on the belief that there is a reserve motivation available within every individual for his doing a better job if he is properly motivated. Third, it assumes that all people are basically honest and fair if they are given an opportunity to be so.

In our company, we back this Plan wholeheartedly. Either I or my executive vice president sits down with a shop committee at least once a month and discusses the past performance of the company as a whole. We also talk about the problems that we see coming up in the future. We talk these things over with the shop committee in full detail. No information is held secret or sacred. Basically, the Scanlon Plan is an information sharing system. There are also subordinate committees to this main shop committee that get together and spend time discussing ways of improving our operations in cutting our costs. This discussion mechanism is significant, I believe, not only because it provides a great deal of information about all aspects of the company's operations to anyone who wants it, but also because through it the worker actually becomes very interested in obtaining this information.

DISCUSSION

Orden: You are using the RAMAC essentially as a gigantic filing and information retrieval system. How many clerks do you think would be required to do the equivalent amount of work in an equivalent length of time?

Atwood: I don't think it would be at all practical to do this task by hand labor if you take into consideration the cost and time involved in relation to the result. For example, every time one shipment leaves our plant, an average of thirty-three records are updated in the RAMAC. I would estimate that this alone would take a week's work under any feasible alternative hand and batch equipment system.

Vogt: We considered this problem of estimating the alternative amount of hand labor our system would require if we had no computer. We concluded that, while it would be theoretically possible to specify the number of people it replaces, it would be impossible in any real situation to organize this number of people and control their activities so as to accomplish the same task.

Alberts: I was quite puzzled about your statement that you had abolished staff in the Atwood Company. After looking at your organization chart, however, and listening to your description of your operations, I concluded that what we call "staff" in United Air Lines, you call "line." It seems to me that all through this Seminar we have been skirting a very important problem—that of definition of this thing called "staff."

Atwood: When I referred to the elimination of staff I meant that we no longer have people in our company whose job it is to look at things and then to recommend or suggest to someone else what this someone else might do. Now, when information or events are looked at, the person doing the looking does the decision-making and the acting.

RUSH: Is this true with reference to the personnel man, too?

ATWOOD: Yes, it is. Our personnel man makes staffing decisions at all but the very highest levels. He also has the power to negotiate contract provisions in our labor contract, relying upon his own discretion totally, if he so chooses. Actually, however, he is usually too intelligent to proceed without consulting others.

VOGT: I believe that Atwood's paper and remarks are quite important in that they supplement two points made by Simon. Simon has stated that the rate of progress of information technology in American business will be partially a matter of technological feasibility and partially a matter of economics. I think that Atwood has suggested a third barrier—and an important one—which must be hurdled. This is the barrier of human acceptance. I believe also that Atwood's company provides an outstanding example of an enlightened management policy toward employees, and that this has paid off for them in the fact that their new information systems have been readily accepted. While Hines and I have probably overemphasized "ramrod" methods, and while we probably do more "selling" than we may have indicated, we still must admit that we have had to apply some force in getting our ideas accepted. I'm confident that this is due, at least in part, to the size of our companies. The Atwood attitude is, I believe, present in our company at top levels, but somehow or another it seems to get lost in filtering down through the long lines of a large organization.

SELECTED BIBLIOGRAPHY

Ackoff, R. L., "Operations Research in Business and Industry, a Report to Management," *Proceedings of the Institute on Operations Research for Business and Industry* (Los Angeles: University of California, 1955), pp. 36–42.

Bechtold, Ira C., "Take a Look at the Automated Gasoline Plant of 1955," *Petroleum Refiner,* XXXVI (February, 1957), 132–39.

Bell, William D., *A Management Guide to Electronic Computers* (New York: McGraw-Hill, 1957).

Chapin, Ned, *An Introduction to Automatic Computers* (Princeton, N.J.: D. Van Nostrand, 1957), esp. pp. 194–97.

The Coming Revolution in Industrial Relations 1955–1975 (New York: Industrial Relations Newsletter, 1955), p. 35.

Crawford, R. W., "Operations Research and Its Role in Business Decisions," American Management Association, *Manufacturing Series, No. 206,* pp. 3–15.

Drucker, Peter F., "The New Management Tools—And What the Manager Can Expect of Them," American Management Association, *General Management Series, No. 176.*

Dudenbockel, B. F., and Priestly, W., "Developments in Process Control Analysis in 1956," *Industrial and Engineering Chemistry* XLIX, January, 1957, pp. 99A–100A.

Forrester, J. W., "Computer Applications to Management Problems," American Management Association, *General Management Series, No. 178,* pp. 22–31.

———, "Indistrial Dynamics," *Harvard Business Review,* XXXVI (July–August, 1958), 37–66.

Hattery, L. H., and Bush, G. P. (editors), *Electronics in Management* (Washington, D.C.: University Press of Washington, D.C., 1956), pp. 157–62.

Hodge, Barton, "Give Your Problems to the Computer," *Petroleum Refiner,* XXXVI (February, 1957), 103–05.

Knight, C. E., and Fawkner, C. H., "The Impact of Automation on the Company Organization," American Management Association, *General Management Series, No. 178*, pp. 11–21.

Kozmetsky, G., and Kircher, P., *Electronic Computers and Management Control* (New York: McGraw-Hill, 1956), esp. Chapter V.

Lasswell, H. D., "Current Studies of the Decision Process: Automation versus Creativity," *Western Political Quarterly*, VIII (1955), 381–99.

"New Tools Will Change the President's Job," *Dun's Review and Modern Industry*, October 1956, pp. 87–94.

Muns, Frank H., "Problems of Decentralization," *Proceedings, Automatic Data Processing Conference*, Harvard University, Sept. 8 and 9, 1955.

Pontius, James W., "Problems of Centralization," *loc. cit.*

Rubinfein, David, and Lewis, R., "Others Use Computers in These Ways," *Petroleum Refiner*, XXXVI (February, 1957), 106–08.

Rush, C. H., Jr., "Implications of Electronic Data Processing for Industrial Relations Research," *Proceedings of the Tenth Annual Meeting, Industrial Relations Research Association.*

Simon, Herbert A., and Newell, Allen, "Heuristic Problem Solving: The Next Advance in Operations Research," *Operations Research* (January –February, 1958), p. 9.

———, "The Logic Theory Machine," *Transactions on Information Theory, Institute of Radio Engineers*, Vol. IT–2 (September, 1956), 61–79.

Slater, R. E., "Thinking Ahead: How Near Is the Automatic Office?" *Harvard Business Review*, XXXVI (March–April), 1958.

Veillette, P. T., "The Impact of Mechanization on Administration," *Public Administration Review*, XVII, No. 4 (autumn, 1957).

Waddell, Richard L., "Communications: Pushbutton Control," *Challenge*, IV (August and September, 1956), 11–15.

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